LIBRARY
BUR. OF COMM. FISH.
HON. BIOL. LAB.

Transactions

of the

American Fisheries Society

SEVENTY-EIGHTH ANNUAL MEETING
ATLANTIC CITY, NEW JERSEY
September 13, 14, and 15, 1948

Published Annually by the Society
Ann Arbor, Michigan
1950

Printed in the U. S. A.

Periodical
American Fish. Society
Trans.
V. 78-80
1948-50

2237 60

Manuscripts are accepted with the understanding that they shall not be submitted for publication elsewhere in the original or in a slightly modified form prior to their appearance in the published TRANSACTIONS; *republications must be made only with written permission of the Secretary and must acknowledge the* TRANSACTIONS.

RALPH HILE, *Editor*

Associate Editors

REEVE M. BAILEY — JUSTIN W. LEONARD
BRIAN CURTIS — GEORGE A. ROUNSEFELL
LLOYD L. SMITH

Assistants to the Editor

WALTER R. CROWE — KIYOSHI G. FUKANO

Copyright, 1950
AMERICAN FISHERIES SOCIETY

Printed by
CRAFT PRESS
Ann Arbor, Michigan

THE AMERICAN FISHERIES SOCIETY

Organized 1870 **Incorporated 1910**

OFFICERS AND COMMITTEES, 1947-1948

Officers

President .....H. H. MacKay, Toronto, Ont.

First Vice-President .....Seth Gordon, San Francisco, Calif.

Second Vice-President .....M. C. James, Washington, D. C.

Secretary-Treasurer [1] .....R. P. Hunter, Hartford, Conn.

Librarian [2] .....Kenneth E. Cobb, Windsor Locks, Conn.

Vice-Presidents of Divisions

Fish Culture .....Oliver R. Kingsbury, Albany, N. Y.

Aquatic Biology and Physics .....Paul R. Needham, Berkeley, Calif.

Commercial Fishing .....A. W. Anderson, Washington, D. C.

Protection and Legislation .....R. W. Eschmeyer, Norris, Tenn.

Angling .....James C. Simpson, Boise, Idaho

---

[1] Mail should be addressed to George E. Sprecher, Wisconsin Conservation Department, Madison 2, Wisconsin. Mr. Sprecher was elected Secretary-Treasurer at the Seventy-eighth Annual Meeting.

[2] Mail should be addressed to William C. Beckman, Colorado Cooperative Fisheries Research Unit, Colorado A and M College, Fort Collins, Colorado. Dr. Beckman was elected Librarian at the Seventy-eighth Annual Meeting.

STANDING COMMITTEES, 1947–1948

Executive Committee

The Executive Committee consists of the president, vice-presidents, secretary-treasurer, librarian, vice-presidents of divisions, and Joe Hogan, the immediate past president.

Committee on International Relations

James N. Gowanloch, *Chairman* ..... New Orleans, La.
George W. Davis ..... Montpelier, Vt.
H. J. Deason ..... Washington, D. C.
J. A. Rodd ..... Ottawa, Ont.
Alan C. Taft ..... San Francisco, Calif.
Fred A. Thompson ..... Santa Fe, N.M.
John Van Oosten ..... Ann Arbor, Mich.

Committee on State and National Relations

Wayne D. Heydecker, *Chairman* ..... New York, N. Y.
A. D. Aldrich ..... Tulsa, Okla.
Albert M. Day ..... Washington, D. C.
John Gottschalk ..... Billings, Mont.
C. R. Gutermuth ..... Washington, D. C.

Committee on Common and Scientific Names of Fishes

Walter H. Chute, *Chairman* ..... Chicago, Ill.
Reeve M. Bailey ..... Ann Arbor, Mich.
W. A. Clemens ..... Vancouver, B. C.
John R. Dymond ..... Toronto, Ont.
Samuel F. Hildebrand [1] ..... Washington, D. C.
George S. Myers ..... Stanford University, Calif.
Leonard P. Schultz ..... Washington, D. C.

Editorial Board

Ralph Hile, *Chairman* ..... Ann Arbor, Mich.
Reeve M. Bailey ..... Ann Arbor, Mich.
Brian Curtis ..... St. Helena, Calif.
Justin W. Leonard ..... Ann Arbor, Mich.
George A. Rounsefell ..... Orono, Me.
Lloyd L. Smith ..... St. Paul, Minn.

[1] Since deceased.

SPECIAL COMMITTEES

Committee on Pollution Study

Kenneth A. Reid, *Chairman*.....Chicago, Ill.
J. S. Dendy.....Auburn, Ala.
A. F. C. Greene.....Laramie, Wyo.
W. J. K. Harkness.....Toronto, Ont.
Willis King.....Raleigh, N. C.
T. H. Langlois.....Put-in-Bay, Ohio
E. W. Schneberger.....Madison, Wis.
S. F. Snieszko.....Kearneysville, W. Va.
Marion Toole.....Austin, Texas

Committee on Revision of Constitution and By-Laws

H. J. Deason, *Chairman*.....Washington, D. C.
W. A. Clemens.....Vancouver, B. C.
George W. Davis.....Montpelier, Vt.
R. W. Eschmeyer.....Norris, Tenn.
Frederick J. Foster[1].....Seattle, Wash.
Seth Gordon.....San Francisco, Calif.
J. A. Rodd.....Ottawa, Ont.

Committee on Formation of Western Division

Fred A. Thompson, *Chairman*.....Santa Fe, N. M.
John L. Hart.....Nanaimo, B. C.
Marion J. Madsen.....Salt Lake City, Utah
Paul R. Needham.....Berkeley, Calif.
William L. Reavley.....Helena, Mont.
Alan C. Taft.....San Francisco, Calif.

Committee to Consider Establishment of a Quarterly Journal

Reeve M. Bailey, *Chairman*.....Ann Arbor, Mich.
John S. Gottschalk.....Billings, Mont.
Ralph Hile.....Ann Arbor, Mich.
Justin W. Leonard.....Ann Arbor, Mich.
E. L. Wickliff.....Columbus, Ohio

Committee on Standardization of Terminology and Procedures

W. J. K. Harkness, *Chairman*.....Toronto, Ont.
Frank E. Eggleton.....Ann Arbor, Mich.
James N. Gowanloch.....New Orleans, La.
William C. Herrington.....A.P.O., San Francisco, Calif.
O. Lloyd Meehean.....Washington, D. C.
Paul R. Needham.....Berkeley, Calif
Edward Schneberger.....Madison, Wis.

Program Committee

A. S. Hazzard, *Chairman*.....Ann Arbor, Mich.
W. A. Clemens.....Vancouver, B. C.
Jack S. Dendy.....Auburn, Ala.
A. G. Huntsman.....Toronto, Ont.
Paul R. Needham.....Berkeley, Calif.
Douglas Omand.....Toronto, Ont.

[1] Since deceased.

PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1.	William Clift	1870-1872	New York, N. Y.
2.	William Clift	1872-1873	Albany, N. Y.
3.	William Clift	1873-1874	New York, N. Y.
4.	Robert B. Roosevelt	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt	1876-1877[1]	New York, N. Y.
7.	Robert B. Roosevelt	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt	1879-1880	New York, N. Y.
10.	Robert B. Roosevelt	1880-1881	New York, N. Y.
11.	Robert B. Roosevelt	1881-1882	New York, N. Y.
12.	George Shepard Page	1882-1883	New York, N. Y.
13.	James Benkard	1883-1884	New York, N. Y.
14.	Theodore Lyman	1884-1885	Washington, D. C.
15.	Marshall McDonald	1885-1886	Washington, D. C.
16.	W. M. Hudson	1886-1887	Chicago, Ill.
17.	William L. May	1887-1888	Washington, D. C.
18.	John Bissell	1888-1889	Detroit, Mich.
19.	Eugene G. Blackford	1889-1890	Philadelphia, Pa.
20.	Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
21.	James A. Henshall	1891-1892	Washington, D. C.
22.	Herschel Whitaker	1892-1893	New York, N. Y.
23.	Henry C. Ford	1893-1894	Chicago, Ill.
24.	William L. May	1894-1895	Philadelphia, Pa.
25.	L. D. Huntington	1895-1896	New York, N. Y.
26.	Herschel Whitaker	1896-1897	New York, N. Y.
27.	William L. May	1897-1898	Detroit, Mich.
28.	George F. Peabody	1898-1899	Omaha, Nebr.
29.	John W. Titcomb	1899-1900	Niagara Falls, N. Y.
30.	F. B. Dickerson	1900-1901	Woods Hole, Mass.
31.	E. E. Bryant	1901-1902	Milwaukee, Wis.
32.	George M. Bowers	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark	1903-1904	Woods Hole, Mass.
34.	Henry T. Root	1904-1905	Atlantic City, N. J.
35.	C. D. Joslyn	1905-1906	White Sulphur Springs, W. Va.

[1] A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

36. E. A. Birge	1906-1907	Grand Rapids, Mich.
37. Hugh M. Smith	1907-1908	Erie, Pa.
38. Tarleton H. Bean	1908-1909	Washington, D. C.
39. Seymour Bower	1909-1910	Toledo, Ohio
40. William E. Meehan	1910-1911	New York, N. Y.
41. S. F. Fullerton	1911-1912	St. Louis, Mo.
42. Charles H. Townsend	1912-1913	Denver, Colo.
43. Henry B. Ward	1913-1914	Boston, Mass.
44. Daniel B. Fearing	1914-1915	Washington, D. C.
45. Jacob Reighard	1915-1916	San Francisco, Calif.
46. George W. Field	1916-1917	New Orleans, La.
47. Henry O'Malley	1917-1918	St. Paul, Minn.
48. M. L. Alexander	1918-1919	New York, N. Y.
49. Carlos Avery	1919-1920	Louisville, Ky.
50. Nathan R. Buller	1920-1921	Ottawa, Canada
51. William E. Barber	1921-1922	Allentown, Pa.
52. Glen C. Leach	1922-1923	Madison, Wis.
53. George C. Embody	1923-1924	St. Louis, Mo.
54. Eben W. Cobb	1924-1925	Quebec, Canada
55. Charles O. Hayford	1925-1926	Denver, Colo.
56. John W. Titcomb	1926-1927	Mobile, Ala.
57. Emmeline Moore	1927-1928	Hartford, Conn.
58. C. F. Culler	1928-1929	Seattle, Wash.
59. David L. Belding	1929-1930	Minneapolis, Minn.
60. E. Lee LeCompte	1930-1931	Toronto, Canada
61. James A. Rodd	1931-1932	Hot Springs, Ark.
62. H. S. Davis	1932-1933	Baltimore, Md.
63. Fred A. Westerman	1933-1934	Columbus, Ohio
64. E. L. Wickliff	1934-1935	Montreal, Canada
65. Frank T. Bell	1935-1936	Tulsa, Okla.
66. A. G. Huntsman	1936-1937	Grand Rapids, Mich.
67. I. T. Quinn	1937-1938	Mexico City, Mexico
68. Fred J. Foster	1938-1939	Asheville, N. C.
69. T. H. Langlois	1939-1940	San Francisco, Calif.
70. James Brown	1940-1941	Toronto, Canada
71. John Van Oosten	1941-1942	St. Louis, Mo.
72. John Van Oosten	1942-1943	(No meeting.)[2]
73. John Van Oosten	1943-1944	(No meeting.)[3]
74. John Van Oosten	1944-1945	(No meeting.)[3]
75. John Van Oosten	1945-1946	(No meeting.)[3]
76. Joe Hogan	1946-1947	St. Paul, Minn.
77. H. H. MacKay	1947-1948	Denver, Colo.
78. Seth Gordon	1948-1949	Atlantic City, N. J.

[2] The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.
[3] No annual meeting scheduled because of the war.

In Memoriam

Barbour, Thomas, Cambridge, Mass.

Grammes, J. Frank, Allentown, Pa.

Pugsley, Winfield B., Flat Rock, N. C.

TABLE OF CONTENTS

	Page
List of officers	3
Standing committees	4
Special committees	5
Past presidents	6
In Memoriam	8

PART I PAPERS

Reduction in the longnose sucker population of Pyramid Lake, Alberta, in an attempt to improve angling. *D. S. Rawson* and *C. A. Elsey*	13
Hydraulic presses for making impressions of fish scales. *John Greenbank* and *D. John O'Donnell*	32
Management of Florida's fresh-water fisheries. *John F. Dequine*	38
The fishery development program in the lower Columbia River. *Leo L. Laythe*	42
A contribution to the etiology of ulcer disease of trout. *S. F. Snieszko* and *S. B. Friddle*	56
Three years of liberalized fishing at Lake Alma, Ohio. *John Z. Pelton*	64
The quantitative effects of a dam upon the bottom fauna of a small California stream. *John Carmon Briggs*	70
Changes in growth rates of fishes following reduction in population densities by winterkill. *William C. Beckman*	82
The fisheries of India—Present status and proposed development. *H. D. R. Iyengar*	91
The apparent thresholds of toxicity to *Daphnia magna* for chlorides of various metals when added to Lake Erie water. *Bertil G. Anderson*	96
A new celluloid opercular tag. *R. A. McKenzie*	114
Sulfonamide therapy of furunculosis in brown trout. *Kenneth G. Flakas*	117
The reintroduction of Atlantic salmon into tributary streams of Lake Ontario. *Hugh R. McCrimmon*	128
Fertilization of lakes in Algonquin Park, Ontario. *R. R. Langford*	133
Fertilization of natural lakes in Michigan. *Robert C. Ball*	145
A nomograph for the computation of the growth of fish from scale measurements. *Ralph Hile*	156
Fish-population and catch data from Minnesota lakes. *John B. Moyle, Jerome H. Kuehn,* and *Charles R. Burrows*	163
The American smelt, *Osmerus mordax* (Mitchill), of South Bay, Manitoulin Island, Lake Huron. *N. S. Baldwin*	176
Various sulfonamide treatments of furunculosis in brook trout, *Salvelinus fontinalis. S. F. Snieszko, J. S. Gutsell,* and *S. B. Friddle*	181
Growth-control charts applied to Atlantic salmon. *George A. Rounsefell* and *Lyndon H. Bond*	189
Toxicity of ferro- and ferricyanide solutions to fish, and determination of the cause of mortality. *George Edgar Burdick* and *Morris Lipschuetz*	192

Part II Business Sessions

	Page
Agenda of seventy-eighth annual meeting	205
Opening remarks of the president	206
Appointment of sessional committees	209
Reports of officers	209
Secretary-treasurer	210
Vice-president, Division of Fish Culture	211
Vice-president, Division of Aquatic Biology and Physics	214
Vice-president, Division of Commercial Fishing	217
Reports of standing committees	220
International relations	220
State and national relations	232
Editorial board	239
Reports of special committees	240
Revision of constitution and by-laws	240
Formation of western division	241
Establishment of quarterly journal	243
Reports of sessional committees	245
Time and place	245
Auditing	245
Resolutions	246
Nominations	252
Concluding business	254

Appendices

Instructions for preparing manuscripts for the Transactions of the American Fisheries Society	257
List of members	261
Index	282

Part 1
Papers

REDUCTION IN THE LONGNOSE SUCKER POPULATION OF PYRAMID LAKE, ALBERTA, IN AN ATTEMPT TO IMPROVE ANGLING

D. S. Rawson and C. A. Elsey

Department of Biology, University of Saskatchewan
Saskatoon, Saskatchewan

Abstract

An attempt was made to reduce the numbers of longnose or northern suckers and mountain whitefish in Pyramid Lake, Alberta, in the hope of improving the survival of introduced rainbow trout. The lake has an area of 320 acres and a maximum depth of 64 feet. Examination of its physical and biological characteristics show it to be oligotrophic and somewhat more productive than most of the other alpine lakes studied in the area. The results of a marking-and-recovery program suggested a population in the order of 27,000 fish of nettable size of which 75 percent were suckers, 22 percent mountain whitefish, and 3 percent game trout of three species. The removal of 27,600 longnose suckers in 7 years has eliminated the older age groups and has reduced the average weight of suckers caught from 5.5 to 1.6 ounces. However, the survival rate of young suckers, less than nettable size, increased. The removal of suckers has not been accompanied by any noticeable improvement in the survival of rainbow trout either during the 5 years of removal or in the 3 years which followed. The present game-fish harvest is less than that expected from a lake of this size. It is suggested that further fish-cultural efforts in this lake be concentrated on the lake trout.

Introduction

Ten years of continuous planting with rainbow trout failed to provide angling for this species in Pyramid Lake although it thrives in other lakes of the area. Since Pyramid was heavily populated with longnose or northern suckers it was thought that competition from this species was probably a factor in the failure. Thus in 1943 intensive gill netting was initiated. This program, continued for 3 years, has not been effective in establishing rainbow trout. The present paper is a report on the progress of the experiment and a record of information obtained as to the ecology of the lake.

Physical and Chemical Conditions

Pyramid Lake lies about 3 miles north of the town of Jasper on the east slope of the Rocky Mountains. It receives most of its inflow from the southeast slope of Pyramid Mountain and has its outlet through Pyramid Creek. This stream, which is about a mile in length and drops some 500 feet to the Athabaska River, is impassable to fish. The lake level is recorded as 3,867 feet.

The water area of 320 acres (1.3 square kilometers) is arranged in a rough horse shoe about 1.5 miles long by 0.3 miles wide. The shores are mostly rocky on the east and sandy to the south and west. One of the three small creeks entering the lake at the west runs through a muskeg with beaver dams. An irregular growth of *Chara* and *Potamogeton* is found on sandy bottom down to 3 meters.

The maximum depth of the lake is 19 meters (64 feet) and the mean 8.7 (28 feet). Depth contours show that 35 percent of the lake area is less than 5 meters deep, 25 percent from 5 to 10, 25 percent from 10 to 15, and 15 percent between 15 and 19 meters.

Lake temperatures have been observed throughout the seasons of 1939, 1943, and 1944. Table 1 includes seven series of observations selected

TABLE 1.—*Temperature (°C.) series in Pyramid Lake*

Depth (meters)	Date of series						
	May 20, 1943	June 14, 1943	July 7, 1944	Aug 2, 1943	Aug 25, 1943	Sept 23, 1939	Oct. 2, 1939
Surface	7.8	15.5	15.0	18.1	16.0	12.8	10.8
5	7.2	13.2	13.	17.7	15.2	12.6	10.8
7	....	....	13.5	16.8	14.9	....	....
9	....	....	10.3	12.0	14.6	....	....
10	6.2	10.8	9.5	11.2	11.7	12.0	10.6
18	5.6	8.4	7.5	8.4	8.6	12.0	10.5

to illustrate the thermal cycle of the lake. The ice usually breaks up about May 4 and the period of full circulation is brief. On May 20, 1943, the surface temperature was 7.8° C, just 2.2 degrees warmer than the bottom. The mean temperature of the lake was 6.9° C. Warming of the upper waters progresses rapidly through June but a sharply defined thermocline is not formed until early July. The extreme thermal stratification observed in any of the three years occurred on August 2, 1943. The mean temperature on this date was 15.5° C. In 1944 the highest mean temperature was 14.2° C., reached on August 30. The autumn turn-over usually takes place in early September (not till after September 11 in 1946) and is followed by a long period of complete circulation which ends at the formation of the ice cover about December 1.

Although located in an alpine area Pyramid Lake is only of moderate depth and it is not fed by any glacial streams. Thus it warms extensively during the summer. The mean temperature of 15.5° C. on August 2, 1943, represents a summer heat income of 10,000 gram calories per square centimeter which is relatively high in view of the shallowness of the lake.

Dissolved oxygen, pH, and transparency were determined along with temperature in each of the three years of observation. The dissolved oxygen in the surface water varied from 5.3 to 7.7 cubic centimeters per liter, representing from 92 percent to a considerable degree of supersaturation. The oxygen of the bottom water varied from 4.3 to 6.9 cubic centi-

meters per liter, (range of 71 percent to 97 percent satuation). Since the lowest oxygen concentration at the bottom was 71 percent of saturation it is clear that the long-continued stratification causes no serious reduction in the oxygen of the hypolimnion.

The hydrogen-ion concentration of the surface water was usually 7.7 or 7.8 while that of the bottom water varied from pH 7.6 down to 7.3 at the height of summer stagnation. Secchi-disc readings indicated a very clear water with transparency from 7 to 10 meters.

Plankton and Bottom Fauna

Quantitative samples of plankton and bottom organisms were taken as an indication of the basic productivity of the lake and as a part of the study of fish food. Plankton was collected and analyzed by the procedure used for a number of other alpine lakes in the Rocky Mountain area and described by Rawson (1942). At each date and station a surface tow and duplicate total vertical hauls were made. The surface tow and one of the vertical hauls were used for microscopic examination. The second vertical haul was used for the determination of dry weight and organic content (by ashing). Seasonal collections were made 3 times in 1939, 5 in 1943, and 12 in 1944. (Table 2)

Table 2.—*Dry weight and organic matter in vertical plankton hauls from Pyramid Lake 1939, 1943, and 1944*

Date	Dry weight (milligrams)	Organic matter (milligrams)	Date	Dry weight (milligrams)	Organic matter (milligrams)
1939			1944		
June 29	30	22	May 29	23	16
Aug. 7	21	16	June 6	24	21
do. 26	36	32	do. 21	43	34
			do. 26	32	26
Average	29.0	23.3	July 7	30	24
			do. 22	41	34
1943			Aug. 2	22	19
May 20	19	14	do. 14	31	25
June 14	28	25	do. 23	23	19
July 12	27	23	do. 30	25	17
Aug. 2	62	52	Sept. 6	29	17
do. 25	25	20	do. 11	30	18
Average	32.2	26.8	Average	29.4	24.2

The plankton was not especially rich either in variety or quantity. The phytoplankton was dominated by diatoms, especially *Asterionella*. Green algae were rare in most hauls. The blue-green *Anabaena* was fairly constant throughout the season but *Microcystis*, usually uncommon, became very abundant in late July 1944. Of the dinoflagellate forms, *Ceratium* was relatively constant and became abundant in July whereas *Dinobryon* was variable and reached pulse-like proportions in early August of 1939 and 1944. Rotifers were common with *Notholca* the most numerous. The larg-

est fraction of the Entomostraca was made up of two species of *Diaptomus. Cyclops, Diaphanosoma,* and *Daphnia* (both *D. longispina* and *D. pulex*) followed in that order. *Bosmina* was relatively constant but present in small numbers.

The quantity of plankton, measured both as dry weight and organic content is indicated in Table 2. The dry weight in most of the total vertical hauls lay between 21 and 43 milligrams. Exceptions occurred on May 20, 1943, when the spring plankton had barely become established after the break-up of the ice and on August 2, 1943, when there was pulse of *Dinobryon* and *Ceratium.* The average quantities in the three seasons were 29.0, 32.2, and 29.4 milligrams and the grand average for all seasons was 30.0 milligrams. In view of the consistency of these measurements it would seem justified to conclude that the average standing crop of net plankton in the central portion of Pyramid Lake was represented by a total vertical haul of 30 milligrams dry weight, of which 24.7 milligrams was organic matter. The nets used had a mouth diameter of 25 centimeters and an efficiency of 26 percent as determined by trap samples at the same stations. Thus the average catch of 30.0 milligrams is equivalent to 23.6 kilograms dry weight per hectare (21 pounds per acre). Four other alpine lakes on the east slope of the Rocky Mountains had from 11.9 to 32 kilograms per hectare (standing crop) of net plankton (Rawson, 1942). Since these lakes are all larger and colder than Pyramid Lake its crop of 23.6 kilograms per hectare is regarded as low.

The bottom fauna was sampled by means of 124 dredgings distributed in all parts of the lake and throughout the summer seasons of 1939, 1943, and 1944. Chironomid larvae dominated the bottom population and made up 65 percent of the total numbers. The sphaeriid *Pisidium* contributed 16 percent and amphipods 11 percent (*Gammarus* 7, *Hyalella* 4). Oligochaetes, leeches, miscellaneous insects, and snails make up the remaining 8 percent. The average number of organisms at all depths was 770 per square meter (645 per square yard) and the average dry weight calculated as 12 percent of wet weight was 3.7 kilograms per hectare (3.3 pounds per acre). This bottom fauna is distinctly poor for a lake of this size and depth. To compare it with other lakes in the region—Minnewanka has 4.5 and Maligne 3.3 kilograms per hectare (Rawson, 1942).

Although the above figures suggest low productivity and oligotrophic conditions in Pyramid Lake, the picture is somewhat incomplete with respect to the availability of food for bottom-feeding fish. The dredgings did not sample the zone from the shore to the depth of 1 meter, and from this zone come large quantities of caddis larvae, other insects, and leeches which will be shown below to form a large part of the food of several fish species. Furthermore, the average figure given includes sphaeriids and oligochaetes which were more abundant in deep water and seldom eaten by fish whereas such forms as amphipods and leeches are most abundant in shallow water and are eaten by fish in proportions much higher than their relative percentage in the total fauna.

Fishes of Pyramid Lake

The fish population of Pyramid Lake includes six species.

Mountain whitefish .....*Prosopium williamsoni*
Rainbow trout .....*Salmo gairdnerii*
Eastern brook trout .....*Salvelinus fontinalis*
Lake trout .....*Cristivomer namaycush*
Longnose sucker .....*Catostomus catostomus*
Lake chub .....*Couesius plumbeus*

The mountain whitefish, longnose or northern sucker, lake chub, and possibly the lake trout, are native. Many rainbow trout, moderate numbers of lake trout, and a few eastern brook trout have been planted in the lake from 1917 to the present.

Fish have been captured in Pyramid Lake chiefly by gill netting with a gang of nets 100 yards long and made up of 25-yard lengths of 1½-, 2-, 3-, and 4-inch stretched mesh. The 4-inch mesh was omitted in the later part of the work since it was too large to catch suckers or whitefish and because it was desirable to avoid catching large lake trout. In the years 1939 to 1945, 328 over-night sets were made with this gang and 26,657 fish caught. Of this total about 75 percent were longnose suckers, 22 percent were mountain whitefish, and the remaining 3 percent were lake trout, rainbow trout, and eastern brook trout. The mountain whitefish is taken in small numbers by anglers and thus, although considered inferior to the trout species, it is not entirely a liability in game-fish production. The vast numbers of northern suckers are of no value for angling and are taken in only insignificant amounts as food by game trout. It was the great predominance of the sucker which prompted the experiment herein reported.

Mountain whitefish.—This species, locally called "grayling" has been noted as making up 22 percent of the gill-net catch and supplying a small portion of the anglers' catch. Its average rate of growth has been estimated by the examination of scales from 51 fish. The lengths which follow below and elsewhere in this report are measured to the fork of the tail.

Age (years)	*Length (inches)*	*Weight (ounces)*	*Age (years)*	*Length (inches)*	*Weight (ounces)*
1	2.5	—	6	10.7	7.6
2	4.0	—	7	12.1	11.0
3	6.0	1.0	8	13.0	14.1
4	7.7	2.8	9	14.0	19.0
5	9.3	5.0	10	15.5	26.0

This growth is almost identical with that of the same species from Lake Minnewanka, Banff (McHugh, 1941).

The food of the mountain whitefish was examined in detail to determine the competition of this species with the rainbow trout. In 120 stomachs collected throughout the season the greatest bulk was of Cladocera (*Daphnia* and *Leptodora*) which contributed 29 percent by volume of the stomach contents. Other foods were: caddis larvae and pupae, 16 percent; mayfly nymphs and adults, 13 percent; *Gammarus,* 11 percent; and chironomid larvae and adults, 11 percent. The remaining 20 percent was made up of miscellaneous terrestrial insects, leeches, and hydrachnids. It is noteworthy that large amounts of Cladocera were eaten by this species which is usually considered a bottom feeder. This habit was not confined to the younger fish but was found commonly in specimens of all ages. A comparable situation was reported in Okanagan Lake by McHugh (1940) who suggested that the high percentage of *Daphnia* eaten was related to the poor bottom fauna in that lake.

Rainbow trout.—This species was first planted in the lake in 1933. Yearly plantings from 1933 to 1939 totalled 239,000 fry. Since that time planting has been continued with smaller numbers but with "fingerlings" about 2 inches long. The total from 1941 to 1944 inclusive was 127,000. It is surprising that in view of these heavy plantings, our 322 gill-net sets, from 1939 to 1945, averaged only 0.4 rainbow trout per set and the species made up only 0.5 percent of the total gill-net catch. The condition of the fish captured was excellent and the rate of growth normal for lakes in this area. Scales from 62 fish were read to establish the following average rate of growth:

Age (years)	*Length (inches)*	*Weight (ounces)*	*Age (years)*	*Length (inches)*	*Weight (ounces)*
1	2.4	0.8	5	11.6	11.3
2	5.3	1.5	6	14.8	21.6
3	7.5	3.0	7	17.9	38.0
4	9.3	5.6			

Analysis of the stomach contents of these 62 rainbow trout shows that amphipods (chiefly *Gammarus*) are the principal food (36 percent of the total volume). Aquatic insects follow: mayfly nymphs and adults, 11 percent; caddis larvae, pupae, and adults, 10 percent; chironomid larvae and adults, 9 percent; and damselfly nymphs and adults, 7 percent. Fish were eaten to the extent of 9.5 percent, of which suckers formed 2.7, lake chub 2.5, and unidentified fish 4.3 percent. Terrestrial beetles contributed 12.5 percent and the remaining 12 percent was of miscellaneous origin.

Lake trout.—The first planting of this species was in 1917 but it may have been native. This supposition is strengthened by its occurrence 20 miles farther up the Athabaska Valley, in Moab Lake for which no planting has been recorded. From 1917 to 1923 plantings in Pyramid exceeded 100,000 fry. A planting of 9,800 fingerlings about 2.5 inches long was made in 1943. The gill-net records suggest that lake trout are not abundant

in Pyramid Lake. They made up about 1 percent of the gill-net catch in the earlier period when no effort was made to avoid catching this species. Creel-census records show that anglers have taken an average of about 60 lake trout annually during the past 5 years.

The average growth of the lake trout as indicated by a study of 56 scales is as follows:

Age (*years*)	*Length* (*inches*)	*Weight* (*ounces*)	*Age* (*years*)	*Length* (*inches*)	*Weight* (*ounces*)
2	6.4	2.0	7	19.5	56.
3	8.9	4.0	8	22.2	85.
4	11.5	8.5	9	24.6	115.
5	14.0	16.0	10	27.0	147.
6	17.0	32.0	11	29.5	189.

The largest trout taken was 36 inches work length, weighed 19.5 pounds, and was at least 13 years old. The growth indicated in the above figures is similar to that in Lake Minnewanka (Rawson, 1939, unpublished) for the first 5 years and somewhat faster in the next 6. The Pyramid Lake trout grew almost twice as fast as the same species in Great Bear Lake (Miller and Kennedy, 1948).

Observations of the spawning of lake trout were made by Hatchery Superintendent W. C. Cable in October 1941 and 1942. They were found to spawn between October 3 and 22, on rocky bottom, in depths of 7 to 25 feet, and in water at a temperature of 10.8° C. A 12-inch lake trout taken on October 9, 1942, had 30 eggs of its own species in its stomach and remains of more in its intestine. Numerous mountain whitefish taken at the same time also contained eggs of lake trout but none were found in the stomachs of longnose suckers captured at the same time and place. Between January 20 and 29 Mr. Cable pumped up 10 lake trout eggs and 40 mountain whitefish eggs from the spawning grounds. The depth was approximately 10 feet and the water temperature was 4.0° C. These eggs were in an advanced stage of development with well formed embryos clearly visible. Further pumping was carried on late in February to determine the rate of development or hatching but unfortunately no lake trout eggs were obtained and only one mountain whitefish egg was taken.

The food taken by 50 lake trout was composed largely of leeches (45 percent) and *Gammarus* (40 percent) by volume. Fish, which made up 7 percent included about equal quantities of lake chub, suckers, and unidentified remains. The remaining 8 percent included aquatic insects, entomostracans, and sphaeriids. It should be pointed out that this sample included few of the large fish and thus may not be representative of the total population particularly with regard to the amount of fish eaten.

Eastern brook trout.—This species was planted in Pyramid Lake about 1931 without official approval. It reproduces in the tributary streams and inhabits beaver ponds but has never become numerous in the lake. In the

gill-net catch it averaged only 0.16 per net. Scales from 35 specimens provide the following data on average growth.

Age (*years*)	*Length* (*inches*)	*Weight* (*ounces*)	*Age* (*years*)	*Length* (*inches*)	*Weight* (*ounces*)
1	5.4	1.5	4	14.0	22.0
2	8.6	5.5	5	16.5	34.0
3	11.1	10.5			

The food of 23 specimens was made up as follows: leeches, 41 percent; *Gammarus,* 22 percent; caddis adults, 13 percent; Odonata, 11 percent; *Couesius* and other small fish, 8 percent; and terrestrial insects, 5 percent.

Longnose sucker.—The northern or longnose sucker has been indicated above as making up 75 percent of the gill-net catch. Consideration will be given later to estimates of population based on recapture of marked fish in 1943, 1944, and 1945.

The average rate of growth based on the examination of 76 specimens may be indicated as follows:

Age (*years*)	*Length* (*inches*)	*Weight* (*ounces*)	*Age* (*years*)	*Length* (*inches*)	*Weight* (*ounces*)
1	2.0	—	7	8.0	4.0
2	3.3	—	8	8.8	5.6
3	4.2	0.8	9	9.6	7.0
4	5.2	1.3	10	10.4	8.5
5	6.0	2.0	11	11.4	10.8
6	7.0	3.2	12	12.4	13.4

Occasional specimens of larger size were taken in the early years of the study; the largest was 16.2 inches long and weighed 29.0 ounces. These values indicate a very slow growth for longnose suckers in Pyramid Lake. They are 4 years old before they become catchable in a gill net of 1½-inch stretched mesh. The same species in nearby Lake Patricia grows one-third faster and in Lake Minnewanka, Banff, faster by one-half. No difference was observed between rates of growth of males and females but the females lived much longer; 99 percent of the fish more than 8 inches long were female.

The small size of the Pyramid Lake sucker lead Bajkov (1927) to describe it as a new subspecies *Catostomus catostomus lacustris.* He stated that it 'never grows to a length of more than 4½ inches." This statement is incorrect since we have taken numerous specimens from 10 to 16 inches long. We have found no reason for taxonomic distinction of this population from the species as it occurs elsewhere in the Athabaska River system.

Spawning of the longnose sucker in Pyramid Lake began about June 10, continued to a maximum in the third week of June, and was usually complete by July 1. Spawning took place in the streams and in certain shallow

rocky parts of the lake. Fish in spawning condition moved freely into the streams at temperatures of 11° to 14° C., but they lingered in the lake near the stream mouth when the inflowing water was at 9° C. or lower. It was observed also that in the years 1943 to 1945 the trap at the mouth of Creek One caught 975 suckers while an identical trap at Creek Two caught only 326. Creek One, which flows through a muskeg and beaver ponds, has a temperature range during the spawning season of 8° to 14° C. Creek Two flows almost directly from the mountain side. Its temperature range for the same period was 4.5° to 7° C. and it cooled rapidly after each fall of snow. The mean difference in temperature between the two streams during the spawning season of the sucker was 4.0° C. Forty percent of the males and 12 percent of the females were sexually mature at 4 years (spawning in their fifth summer). At 5 years 65 percent of the males and 20 percent of the females were mature and at 6 years all individuals were mature.

The food of the longnose sucker was of particular interest as evidence of the degree of competition between this and other species in the lake. Young suckers, less than 2 inches long differed from the larger fish in the food taken. Analysis of the contents of 25 stomachs showed that the young had eaten mostly zooplankton. Cladocera of 8 species made up 66 percent of their food. Other items were: *Cyclops,* 4 percent; chironomid larvae and pupae, 6 percent; *Gammarus,* 1 percent; and terrestrial insects, 23 percent. The food of 110 larger specimens was examined. Amphipods contributed 72 percent of the total volume of food (*Gammarus* 53 and *Hyalella* 19 percent). Additional food items were: Chironomid larvae and pupae, 19 percent; mayfly nymphs, 5 percent; Cladocera, 1.5 percent; sphaeriids, 1.2 percent; snails, 0.6 percent, and miscellaneous, 0.7 percent. No important seasonal differences in the food taken were detected during the period of May to September. A comparable study of the food of suckers in Patricia Lake just one-third of a mile south of Pyramid, shows a much greater dependence on chironomids (40 percent as compared with 19) and correspondingly smaller quantities of amphipods.

Two helminth parasites were common in the suckers of Pyramid Lake. A close examination of 480 specimens revealed larvae of *Ligula* sp. in the coelom of 18 percent and adult *Glaridacris catostomi* in the intestine of 30 percent.

Lake chub.—This species is abundant in the shallow-water areas. One thousand specimens taken in seines and minnow traps ranged from 1 to 4.5 inches in fork length. The average (inches) at different ages were: 1 year, 1.1; 2 years, 1.9; 3 years, 2.8; and 4 years, 4.5. The food of small individuals was mainly cladocerans and copepods. Larger fish had eaten aquatic and terrestrial insects,

Competition among species for food.—From the foregoing analyses of stomach contents it is evident that there is much duplication in the kinds of food taken by the various species. The extent of this competition is suggested by Table 3. Since amphipods are the main food of the longnose

sucker, that fish competes strongly with the main game species—rainbow trout and lake trout. Aquatic insects are the other major element in the food of game fish and here the mountain whitefish is the chief competitor. The large amounts of Cladocera eaten by the mountain whitefish put it into competition with the young of almost all other species of fish in the lake. From the standpoint of food competition alone, the attempt to improve survival of rainbow trout by reducing the number of suckers and mountain whitefish would seem to be justified.

TABLE 3.—*The average percentage by volume of the main foods taken in Pyramid Lake by five species of fish*

Food item	Species				
	Longnose sucker	Mountain whitefish	Lake trout	Rainbow trout	Eastern brook trout
Amphipods	72	11	40	36	22
Aquatic insects	24	46	..	37	24
Cladocera	2	29	2	..	..
Terrestrial insects	..	6	..	12	5
Fish	..	..	7	10	8
Leeches	..	..	45	..	41

REDUCTION OF THE POPULATION OF LONGNOSE SUCKERS

Reduction in the number of suckers was recommended after the biological survey of the lake in 1939. Gill nets, traps, and seines were used by Mr. Cable as opportunity allowed in the years 1940, 1941, and 1942. In the years 1943 to 1945 a more intensive attack was made possible by grants from the National Committee on Fish Culture. A continuous program of netting was carried on in the summer months of 1943 and the opportunity was taken to obtain information as to the size of the population by the markings-and-recovery method. Similar procedures were used in 1944 and 1945. The catches of suckers from netting in the years 1939 to 1945 are summarized in Table 4.

A total of 27,597 longnose suckers weighing 5,171 pounds was recorded as removed in the 7-year period. About two-thirds of these fish were taken in gill nets and the remainder in wire-mesh traps set to catch the fish as they entered the streams. An additional 5,500 small suckers were taken by seining in the years 1941 to 1945. These fish have not been included in the table since they were less than 4 inches long and thus do not belong to the population of "nettable size," that is fish of 5 inches or more in length.

The early success of stream traps which took 3,534 fish in 1941 and the great decrease in their catch in subsequent years are striking features of Table 4. The main reason for the drop in catch is believed to be the decrease in the average size of the fish beyond the point where they could be retained effectively in the regular 1-inch-bar galvanized chicken wire. Table 4 shows a regular decrease in the average weight of fish caught by

gill nets from 5.4 ounces in 1940 to 1.65 ounces in 1945. Replacement of the wire of the stream traps with ½-inch mesh in 1945 was accompanied by an increase from 67 fish in 1944 to 984 in 1945. A further explanation of the poor trap catches in 1943 and 1944 may be found in the creek temperature which as indicated above, affect the entrance of suckers into the streams. In 1943 the air temperature in May and June averaged 3.4° F. below the long-term mean for Jasper and the water temperatures in Creeks One and Two averaged 4.0° C. lower than in 1945. In 1944 air temperatures were close to average but precipitation in May and June was 2.3 times the long-term mean. A part of this precipitation falls as snow on Pyramid Mountain and has a marked cooling effect on the streams. Daily observations showed that creek temperatures during the spawning season of 1944 averaged 1.1° C. lower than those of 1945. Air temperature and precipitation in 1945 were close to the long-term average and creek temperatures were more favorable for the sucker run than in 1943 and 1944.

The average catch per 100-yard gill net decreased from 221 in 1941 to 48.5 in 1944. This decrease obviously reflects a decline in availability resulting from the netting program. The increase from 47.5 in 1944 to 63.5 in 1945 is interpreted as an indication of increased survival of young suckers made possible by the removal of adults. It will be noted that the first

TABLE 4.—*Numbers and weight of longnose suckers removed from Pyramid Lake with gill nets and traps, 1939 to 1945*

Year	Gill nets					Wire-mesh traps		
	Number of sets	Number of fish	Average per net[1]	Average weight of fish (ounces)	Total weight of catch (pounds)	Number of fish	Average weight of fish (ounces)	Total weight of catch (pounds)
1939	4	733	183	3.12	143	.....	...	.....
1940	3	663	221	5.40	224	.....	...	.....
1941	6	788	131	5.32	262	3,534	5.5	1,220
1942	2	255	127	2.25	36	2,438	5.5	845
1943	102	5,973	58	2.25	840	658	4.0	164
1944	126	6,113	48	1.95	745	67	3.3	14
1945	85	5,391	63	1.65	555	984	2.0	123
Total	...	19,916	...	....	2,805	7,681	...	2,366

[1] 100 yards, made up of four pieces, 1½-, 2-, 3-, and 4-inch stretched mesh

major catch was 4,322 in 1941. The young spawned in 1941 would be 4 years old and from 4.4 to 5.7 inches long in 1945. Thus they would enter the gill-net catch of the latter year.

Monthly variations in the catch per gill net, which were noted in the years 1943, 1944, and 1945, followed the same pattern in each year. Beginning about May 20, the first week of netting averaged about 75 suckers per net. The maximum of about 95 per net was reached during the first week in June. The catch then declined steadily to 60 at the first of July and a minimum of 25 to 30 in the first week of August. In 1944 an increase up to about 50 per net was observed in the catch of late August and

early September. This rise did not occur in 1943 and netting ceased in August in 1945. The main reason for the decline from 95 per net in early June to less than 30 per net in early August is believed to be the movement of suckers into deep water and the scattering over a wider area which took place as the warming of the epilimnion progressed. The reduction in the numbers of catchable fish in the lake is also involved but judging by the values calculated below for the total population this factor might account for a reduction in the catch per net of the order of one-fifth as compared to the two-thirds reduction observed.

Day-and-night gill-net catches were compared in order to assess the importance of the number of hours the nets were left in the lake. Four sets were made on different days. The net was set at 8:30 a.m., lifted at 8:30 p.m., reset immediately and lifted the following morning at 8:30 a.m. No fish were taken in the 12-hour day sets but the over-night sets took from 44 to 78 fish per net. It was assumed that for this species in Pyramid Lake the exact number of hours was not important provided that the net was left in the water all night.

The increase in the number of fish caught in 1945 over that of 1944 (Table 4) suggests that the netting program was reaching the limit of its usefulness and that removal of larger suckers was simply making way for increased survival of the young. It is true that the total weight of fish taken by nets decreased in 1945 as compared with 1944 but it seemed quite possible that the survival of larger numbers of young suckers might even increase the food competition of this species with young rainbow trout beyond that existing prior to the experiment. Moreover, since the suckers in Pyramid Lake begin spawning in the same year in which they become catchable in our small-mesh gill nets, there was no hope of eliminating the spawning population by netting.

The effect of intensive netting on the age-group composition of the population of longnose suckers can be seen in Table 5 which shows the

TABLE 5.—*The age composition of longnose suckers caught by gill nets in Pyramid Lake in 1939, 1943, 1944, and 1945*

Year	Percentage of catch in each age group										
	4	5	6	7	8	9	10	11	12	13	14
1939	11.0	28.0	11.5	14.0	13.0	7.0	4.5	5.0	4.0	1.5	0.5
1943	5.0	33.5	8.5	21.5	20.0	7.5	3.0	1.0	....	....	....
1944	21.5	56.5	6.0	12.0	3.0	0.5	....	....	....	....	....
1945	7.0	76.5	10.0	5.5	1.0	....	....	....	....	....	....

percentage contributed by each age group to the gill-net catches of 1939, 1943, 1944, and 1945. It will be seen that age-groups 9 to 14, which represented 22.5 percent of the catch in 1939 had been practically eliminated by 1945. In the same period the percentage of 5-year-old fish increased from 28.0 to 76.5. These data are presented graphically in Figure 1. Smooth

curves have been drawn to show the approximate age composition of the catches in each of four years. The number of fish in the 6-year group was consistantly small in all years. This low representation has been found to be the result of selectivity of our gill nets. The 6-year fish, which range from 5.6 to 6.5 inches in length, are of a size not caught effectively by either the 1½- or 2-inch mesh. For this reason the values for the 6-year group

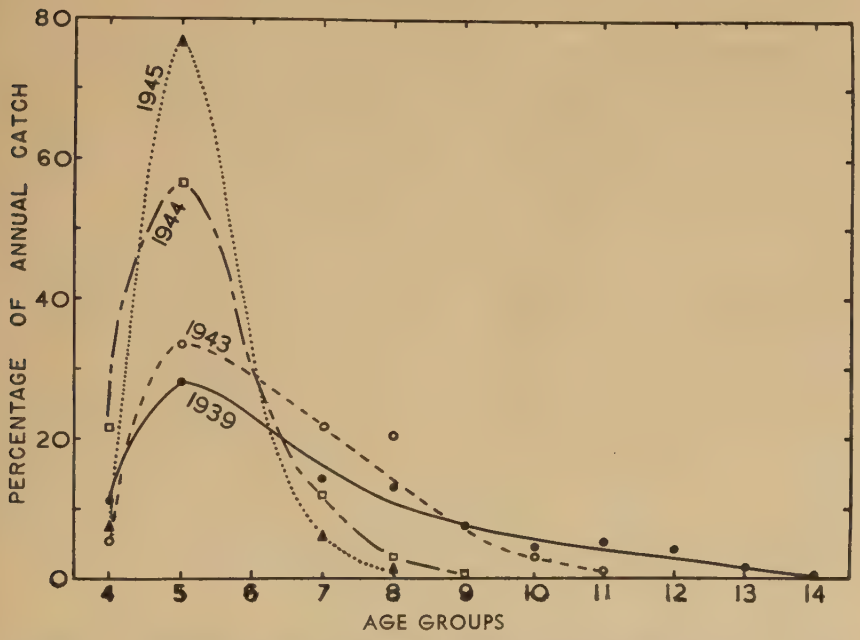

FIGURE 1.—Progressive changes in the age composition of gill-net catches of northern suckers in Pyramid Lake 1939 to 1945. The percentage values for the individual age groups are shown by solid circles for 1939, open circles for 1943, open squares for 1944, and solid triangles for 1945.

have been ignored in drawing the curves in Figure 1. It is apparent from these curves that there has been a progressive reduction in the older age groups and a pronounced increase in the proportion of 5-year-old fish in the annual catch. When the percentage data in Table 5 and the average numbers per net in Table 4 are considered together it will be seen that there was an absolute as well as a relative increase in the 5-year group. Thus in 1943 the average number of 5-year fish per net was 19.6, whereas it was 26.8 in 1944 and 48.5 in 1945.

The increased numbers of 5-year-old suckers per net must indicate an increased recruitment which might result from increased survival of younger fish, from accelerated growth, or from a combination of the two.

The examination of scales taken in 1944 did not demonstrate any change from the growth rate in 1943. The 4-year fish made up 21.5 percent of the catch in 1944 but only 7.0 percent in 1945 (Table 5). If the rate of growth had increased, a larger rather than a smaller number of 4-year fish should have entered the gill-net catch in 1945. Thus we conclude that the reduction in numbers of larger suckers in Pyramid Lake resulted in an increased survival of young suckers but had no measurable effect on the rate of growth up to 1945.

The effects of removing 27,000 longnose suckers as described above may be contrasted with the absence of any important change in the mountain whitefish of which 6,000 were removed. The average weight per fish in this species was 6.0 ounces in the 1943 catch, 4.95 in 1944, and 4.93 in 1945. The average number of fish per net was 17.5 in 1943, 16.9 in 1944, and 18.9 in 1945.

Estimation of the Fish Population

In each of the years 1943, 1944, and 1945 attempts were made to determine the total population of nettable longnose suckers by releasing marked fish and observing the proportion of marked to unmarked fish in the subsequent catch. Between June 30 and July 5, 1943, 100 suckers caught in a trap set in the lake, were marked by the removal of the left pectoral fin and released. Thirteen of these fish were recaptured up to August 25. The Schnabel (1938) formula was used to calculate the population: *i.e.*, $P = \Sigma AB \div \Sigma C$ when A is the total number of suckers caught on any day, B is the number of marked fish at large on that day, and C the number of marked fish recovered on that day. On this basis the number of suckers, of a size catchable in our gill nets, present on June 30 was 15,816. When 4,246 caught previous to this time are added the population of nettable size at May 20 is estimated at approximately 20,000.

In 1944, 150 suckers were marked by fin-clipping and released on June 23 and July 13, 14, and 15. Since trap-caught fish were not available these fish were taken from gill nets. When netting ceased on September 14, only 4 of these marked fish had been recaptured. The population estimate from this return is 106,200 which would seem to be much too high. The small return of marked fish is attributed to damage caused by the gill net aggravated by handling and fin-clipping at a time when the water was warm.

In 1945 marked fish were again released—100 taken from traps on May 28 and 50 from gill nets on May 30. Thirty-four of the former and 12 of the latter were recovered. The population estimate from the trap-caught fish is 11,335 and that from the gill nets 16,103. The combined estimate was 12,500. The gill-net fish gave a smaller proportionate return which fact is presumed to indicate a higher mortality than existed among the trap-caught fish. However, the return was 24 percent as compared to less than 3 percent return of fish caught by gill net in 1944. It should be pointed out that the 1944 fish were caught, marked, and released from June

23 to July 15 when the surface water hanged from 15 to 17.5° C. whereas the 1945 fish were released in cold water (about 12° C.) on May 30. Since three other estimates range from 11,300 to 20,000 and since the 1944 fish were marked under unfavorable circumstances, the rejection of the 1944 population estimate would appear to be justified.

If the estimates of 20,000 longnose suckers in 1943 and 11,300 in 1945 are accepted as reasonable we may calculate the weight in 1943 as 2,800 pounds or 8.8 pounds per acre and that in 1945 as 1,300 pounds or 4.1 pounds per acre (estimates based on the average weight per fish recorded in Table 4).

In order to see the sucker catch in relation to that of other species Table 6 has been constructed to show the numbers of fish of all species

Table 6.—Total catches in standard gangs of gill nets in Pyramid Lake for the years 1939 to 1945

Year	Total number captured					
	Number of sets	Longnose sucker	Mountain whitefish	Lake trout	Eastern brook trout	Rainbow trout
1939	4	733	154	8	1	1
1940	3	663	12	0	0	2
1941	6	788	207	15	2	5
1942	2	255	108	5	2	4
1943	102	5,973	1,783	14	21	84
1944	126	6,113	2,131	36	16	295
1945	85	5,391	1,605	91	12	127
Total	328	19,916	6,000	169	54	518
Average per net	...	60.7	18.3	0.52	0.16	1.58
Percentage of catch	...	74.7	22.5	0.6	0.2	1.9

taken in the gill nets during the years 1939 to 1945. The suckers made up 74.7 percent of the catch, the mountain whitefish 22.5 percent, and the three trout species 2.7 percent. The value of 0.5 percent for lake trout is undoubtedly too low since the 4-inch-mesh net was not used in the latter part of the experiment. A value of 1 percent is more nearly correct since this figure is the proportion observed in the earlier sets with the full gang of nets. If it is assumed that the gill nets catch other species with the same efficiency as they take suckers, a picture of the total fish population of catchable size can be built up as follows for 1943.

Species	*Number of fish*	*Weight (pounds)*
Longnose suckers	20,000	2,800
Mountain whitefish	6,000	2,200
Lake trout	200	500
Eastern brook trout	56	35
Rainbow trout	540	100
All species	26,796	5,635

This hypothetical population is equivalent to 84 fish and 17.5 pounds per acre. Rounsefell (1946) in his analysis of the total poundage of fish in lakes of different area, calculates an average of 28 pounds per acre for a lake of this size. It is not surprising that Pyramid Lake in its alpine surroundings should support a fish population about two-thirds as heavy as the average for lakes of comparable area.

Effects of the Removal of Competitors on the Game-Fish Situation

In the years following 1930 a small number of lake trout and mountain whitefish were taken annually in Pyramid Lake. Angling was decidedly poor and planting of rainbow trout was urged to remedy this situation. When six years of heavy planting failed to bring about any improvement, it was recommended in 1939, that a netting program be instituted to reduce the number of competitor fish. After 7 years of netting and the removal of 27,600 longnose suckers it is desirable that the status of the game fish should be re-examined.

The lake trout continues to provide a small number of fish to anglers. Creel censuses in the years 1944 to 1948 show an average of 67 lake trout per year and an average weight per fish of about 2.5 pounds. The creel census from this lake is not complete but Mr. Cable estimates that approximately two-thirds of the catch is recorded. Gill-net records discussed above suggest a modest population of this species—probably less than one catchable fish per acre.

The rainbow trout has not shown any marked increase following the removal of competitor fish. Figures from Table 6 show that in 12 gill-net catches in the years 1939 to 1942, rainbow trout averaged 0.8 per net. In 1943, when 102 sets were made, the average was again 0.8; in 1944 it was 2.3 (126 sets) and in 1945 it was 1.5 (85 sets). These averages suggest a sparse population of about 1.5 fish and 4.5 ounces per acre. The anglers' catch reported in a creel census in 1947 was 26 rainbow trout and in 1948 only 8.

The mountain whitefish, although not highly regarded as a game fish, continues to provide some angling. The 1947 creel census shows 72 of this species. The numbers of eastern brook trout taken are insignificant. Two were reported in the 1947 census.

The annual catch of all species taken by angling is estimated roughly as 200 fish weighing about 260 pounds and equivalent to 0.8 pound per acre. This estimate is based on the assumption that the creel census includes about two-thirds of the fish taken by angling. Rounsefell's (1946) average for game-fish production for a lake of this size was 2,560 pounds or 8 pounds per acre, and he recorded production ranging from 2 to 40 pounds per acre. Rounsefell's data did not include pertinent records of game-fish production for certain lakes in the Algonquin Park, Ontario. Fry (1939) reported maximum annual removal from three "lake trout" lakes as follows: Merchant Lake (1.5 square miles), 2.8 pounds per acre; Redrock Lake (1.4 square miles), 1.3 pounds per acre; and Whitegull Lake (0.2

square mile) 1.9 pounds per acre. Average production from Lake Opeongo over a 10-year period has been 0.39 pound per acre made up of 0.31 pound of trout and 0.08 pound of black bass. (Fry, personal communication, February 1949).

It is now evident that we have little reason to hope for a successful rainbow trout fishery in Pyramid Lake. Since the lake trout is the main predaceous fish it seems probable that its feeding has been the important factor in the failure of the rainbow trout. The lake trout now provides more than 80 percent of the weight of game fish taken by anglers. The lake is too large and too deep for elimination of the lake trout population by methods now available. It is suggested therefore, that future efforts in fish culture at Pyramid Lake should be concentrated on the production of more lake trout. It is of interest that a similar conclusion was reached with regard to Clear Lake, Manitoba (Rawson, 1948) after the failure of an attempt to introduce rainbow trout into a "mixed fish" population.

During the 5-year period 1941 to 1945 an average of 5,240 longnose suckers were taken annually from a catchable population estimated from 11,000 to 20,000 fish. The results of this removal include the elimination of the 9- to 14-year age groups and the reduction of the average size of suckers caught from 5.4 to 1.6 ounces. Perhaps the increased survival of young suckers nullified the effect of reducing the adults. In any case, we have been unable to demonstrate any improvement in game fishing during the 5-year period or in the 3-years which followed.

Despite the common assumption that reducing the numbers of coarse fish will improve game-fish production there are few published reports showing success with this procedure. Ricker and Gottschalk (1941) reported the removal of large quantities of coarse fish, chiefly carp, quillback, and buffalo, from Bass Lake, Indiana, in the years 1935 and 1936. This removal was followed by a great increase in the numbers of game fish taken by anglers in 1936 and 1937. Foerster and Ricker (1941) reported that the survival of young red (sockeye) salmon in Cultus Lake increased nearly three-fold as a result of removal of predaceous fish by gill netting. Neither of these experiments is fully comparable to that at Pyramid Lake since the former was conducted on a dense population of fast-growing, warm-water fish and the latter dealt with predaceous rather than competitor species. Further tests of the effect of removing competitor fish from game-fish waters would be highly desirable.

Summary and Conclusions

1. Pyramid Lake, Alberta, has an area of 320 acres and a maximum depth of 64 feet. Examination of physical and chemical conditions, plankton, and bottom fauna show it to be oligotrophic but somewhat more productive than other alpine lakes studied in the area.

2. The abundance, rates of growth, and food are recorded for each of the six species of fish in the lake. Special observations on the life histories of the longnose sucker and the lake trout are included.

3. The longnose sucker makes up about three-quarters of the fish population of the lake. Competition by this species was considered a main factor in the low survival of rainbow trout planted in the lake.

4. In the years 1941 to 1945 more than 27,0000 suckers of nettable size were removed from the lake. This removal eliminated the age-groups 9 to 14 and reduced the average weight of suckers caught in gill nets from 5.4 to 1.6 ounces. The average catch per net declined in the first 4 years but increased in the fifth. Apparently the drastic reduction in the number of larger fish permitted an increased survival of the younger age groups. No evidence was obtained of increase in the rate of growth of suckers during the period 1943 to 1945. Longnose suckers in Pyramid Lake enter the gill-net catch (1½-inch mesh) when 4 years old and about 5 inches long. They also begin to spawn at 4 years. Thus there was no hope of eliminating the spawning population with gill nets.

5. In the years 1943 to 1945 the mountain whitefish population was reduced by 6,000 fish. There was a slight reduction in the average size of fish caught but no decrease in availability as measured by the average catch per net.

6. Population estimates obtained by the marking-and-recovery method, indicate that in 1943 the sucker population included about 20,000 and in 1945 about 11,300 nettable fish. These figures indicate a reduction in numbers of 44 percent and in weight of 83 percent. The hypothetical population of all species of nettable size was calculated for 1943 as 84 fish and 17.5 pounds per acre—about two-thirds the average weight per acre for lakes of this size. Creel-census data indicate that the anglers' catch of game fish averages about 0.8 pound per acre annually. This take is extremely low as compared to the catch in most lakes producing game fish.

7. There was no detectable improvement in the survival of rainbow trout during the 5-year period in which the population of longnose suckers was being reduced nor in the 3 years which followed. Perhaps the increased survival of young suckers largely nullified the expected decrease in food competition. It is suggested that the removal of coarse fish from cold, trout-producing lakes may not prove as helpful as it has been in certain warm-water lakes.

8. Since the lake trout now provide most (80 percent) of the weight of the anglers' catch and since its predaceous habits may be preventing the establishment of rainbow trout, it is recommended that future fish-cultural efforts should aim at improving the production of lake trout.

Acknowledgements

The investigation of Pyramid Lake was made possible by grants in the years 1943, 1944, and 1945 from the National Research Council of Canada through the National Committee on Fish Culture. Thanks are also due to the National Parks Bureau for cooperation and material assistance in the field work. We wish to acknowledge especially our indebtedness to Hatchery Superintendent W. C. Cable who gave uncreasingly of his time and whose residence in Jasper made possible the extension of observations into seasons when the authors could not be in the field.

Literature Cited

Bajkov, A.
1927. Reports of the Jasper Park lakes investigations, 1925–26. I. The fishes. Contr. Can. Biol. and Fish., N. S., Vol. 3, No. 16, pp. 379–404.

Foerster, R. E., and W. E. Ricker
1941. The effect of reduction of predaceous fish on survival of young sockeye salmon at Cultus Lake. Jour. Fish. Res. Bd. Can., Vol. 5, No. 4, pp. 315–336.

Fry, F. E. J.
1939. A comparative study of lake trout fisheries in Algonquin Park, Ontario. Univ. Toronto Stud., Biol. Ser. 46, Pub. Ont. Fish. Res. Lab., No. 58, pp. 1–69.

McHugh, J. L.
1940. Food of the Rocky Mountain whitefish *Prosopium williamsoni*. Jour. Fish. Res. Bd. Can., Vol. 5, No. 2, pp. 131–137.
1941. Growth of the Rocky Mountain whitefish. Jour. Fish. Res. Bd. Can., Vol. 5, No. 4, pp. 337–343.

Miller, R. B., and W. A. Kennedy
1948. Observations on the lake trout of Great Bear Lake. Jour. Fish. Res. Bd. Can., Vol. 7, No. 4, pp. 176–189.

Rawson, D. S.
1942. A comparison of some large alpine lakes in Western Canada. Ecology, Vol. 23, pp. 143–161.
1948. The failure of rainbow trout and initial success with the introduction of lake trout in Clear Lake, Riding Mountain Park, Manitoba. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 323–335.

Ricker, W. E., and John Gottschalk
1941. An experiment in removing coarse fish from a lake. Trans. Am. Fish. Soc., Vol. 70 (1940) pp. 382–390.

Rounsefell, George A.
1946. Fish production in lakes as a guide for estimating production in proposed reservoirs. Copeia, 1946, No. 1, pp. 29–40.

Schnabel, Zoe E.
1938. The estimation of the total fish population of a lake. Am. Math. Monthly, Vol. 45, pp. 348–352.

HYDRAULIC PRESSES FOR MAKING IMPRESSIONS OF FISH SCALES

John Greenbank

Wisconsin Conservation Department
La Crosse, Wisconsin

and

D. John O'Donnell

Wisconsin Conservation Department
Madison, Wisconsin

Abstract

Two types of hydraulic press have been designed and constructed for making impressions of fish scales on cellulose acetate. One of these presses is hand-operated; the other is powered by an electric motor. Each has a heated die to soften the plastic material. In growth studies the use of acetate impressions in place of the scales themselves results in a marked saving of time, materials, and storage space. Operation of the scale press is relatively simple, and the technical difficulties are relatively few and are corrected easily. Certain modifications and improvements are suggested.

Introduction

The use of scales for the determination of age and growth of fish is familiar to fishery workers. Systems and formulae have been set up for the analysis of data from the scales of many species of fish. The usual technique has been to select scales by examination under a low-power microscope, wash them, and mount them in gelatin or other medium on a glass slide. Examination and measurements are then made with the aid of a micro-projector.

Several years ago the staff of the North Atlantic Investigations, U. S. Fish and Wildlife Service, developed a roller press for making scale impressions on plastic material. Later, Lyle M. Thorpe and his associates in the Connecticut Board of Fisheries and Game designed a screw press for making impressions. This type of press is now sold by a limnological-supply company, under the name "Connecticut fish scale press." Usually the plastic is unheated, but is softened by a liquid solvent, such as acetone.

We have devised and constructed, first a hand-operated hydraulic press, and later a hydraulic press powered by an electric motor. Each of these presses has an electrically heated die. Contact with this die, under pressure, softens the plastic, so that no solvent is needed. In the design and develop-

ment of these scale presses we have had much valuable aid from D. W. Cameron, a machinist in La Crosse, Wisconsin. Suggestions for modification and improvement have been received also from Lyman Williamson and other biologists in the Fish Management Division of the Wisconsin Conservation Department.

Both of these presses have been in use for some time, and have proved to be highly efficient for preparing impressions of scales. The plastic impressions have certain advantages over gelatin scale mounts. It saves considerable time. Scales can be selected rapidly, and usually no cleaning is needed. Pitting or other irregularities on the inner surface of the scales sometimes interferes with light transmission in whole mounts sufficiently to make age determination impossible. These defects, of course, do not appear on impressions, which are taken from the outer surface of the scale. The plastic slide is unbreakable; and storage in slide boxes is eliminated by storing the impressed slide in the scale envelope along with the scale sample. Details of construction of the two presses are given here for the benefit of other fishery workers who may wish to adopt this method of handling scales.

Hand Press

The construction of the hand-operated press is shown in Figure 1, with the dies in open position.

The basic unit is a 1½-ton hydraulic automobile jack, mounted in a skeleton frame made of steel plates and rods. The over-all height is 12½ inches. The top and bottom plates are equilateral triangles made of 1-inch steel plate, 9 inches on a side. The upper die is fixed to the plate; the lower die is attached to the jack, and is movable in relation to the upper die. This lower die, or contact plate, is made of 1½-inch steel bar, welded directly onto the lift of the jack. At each end it has a return spring and guide pin.

The upper die, or contact, is essentially a steel box, with the bottom ½-inch and the sides ¼-inch thick. This die box, which is attached to the upper triangular plate by four bolts, contains the heating element. The heating unit consists of two 750-ohm fixed resistors, mounted in series. The electric cord (asbestos covered) enters the box through a hole in the side. The resistors are laid on the bottom of the box, and the remaining space is filled with asbestos. The two dies are milled flat and polished, to provide a perfectly uniform contact. The six nuts holding the upper triangular plate are used to adjust the seating of the die surfaces.

Electric Press

The construction of the electrically operated press is shown in Figure 2.

The basic unit is a 5-ton hydraulic jack mounted in a welded steel frame. The pressure release is a short rod, with a hand wheel. The plunger of the hydraulic jack is driven by a cam-and-shaft arrangement which is con-

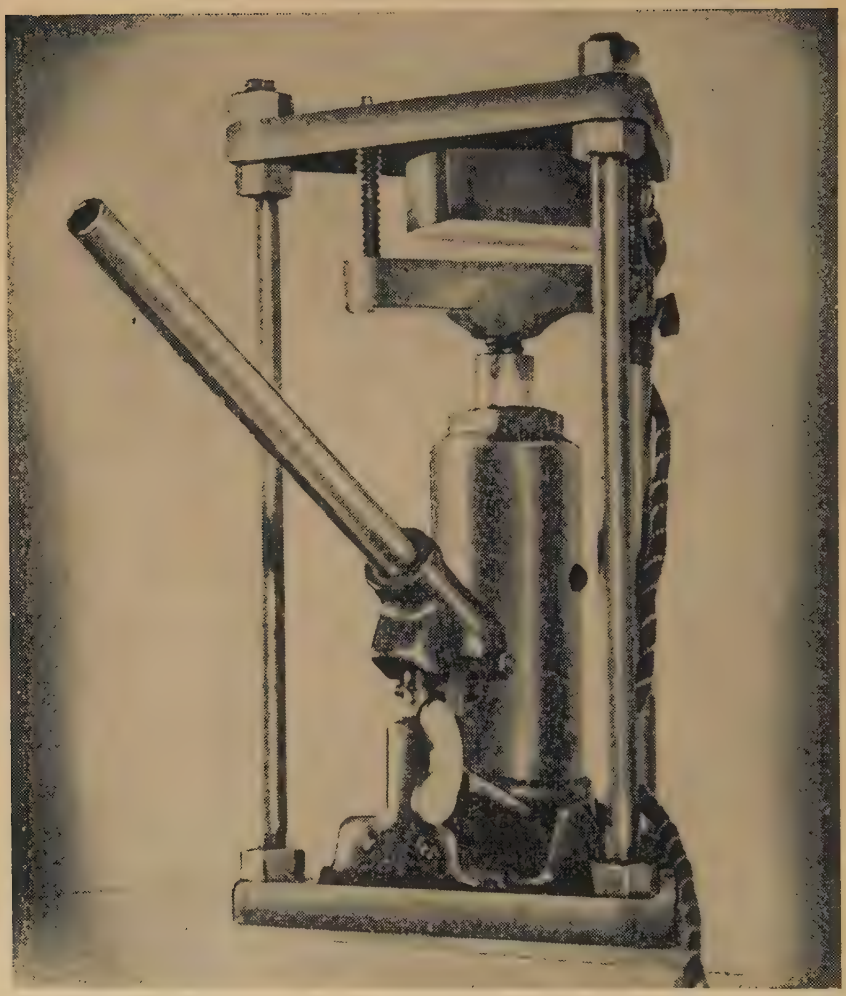

FIGURE 1.—Hand-operated press for making impresions of fish scales on cellulose acetate. (Photograph by Kenneth Flakas.)

nected to an electric motor by a V-belt drive. A foot-pedal switch is provided.

The movable lower die rides in the channels of the side members of the frame, and is supplied with guide pins and return springs. The height-adjustment screw of the jack is used to regulate the working space between the dies. The fixed upper die is made of two blocks of ½-inch steel, between which is inserted a flat heating element of 1,000-watt capacity.

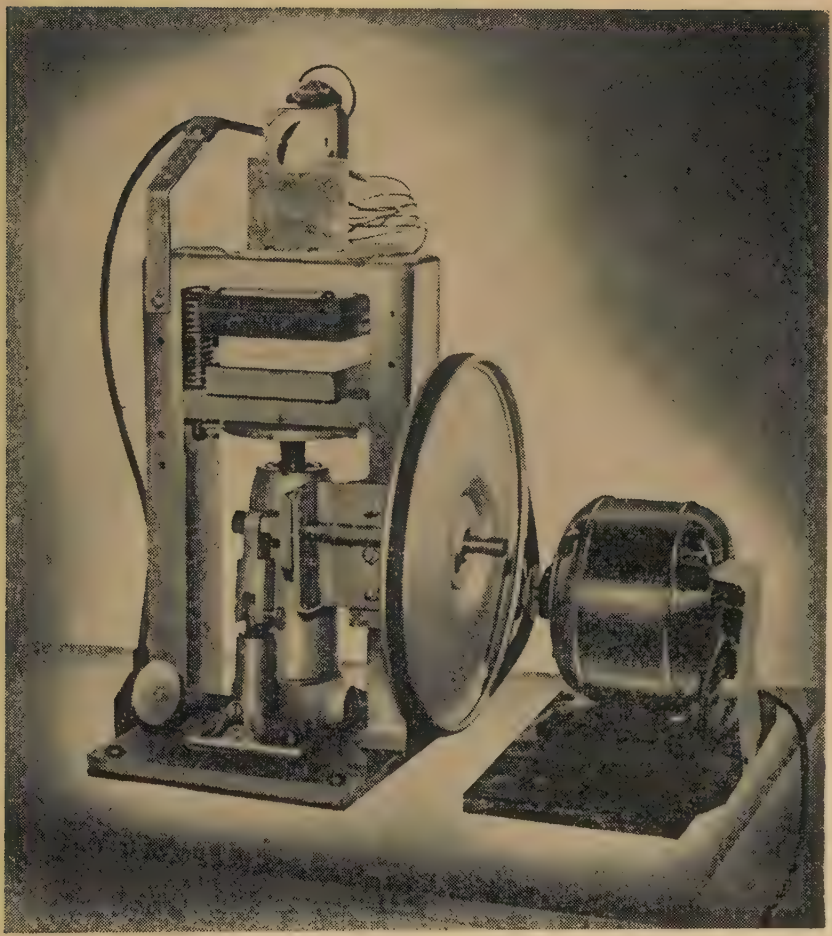

FIGURE 2.—Electrically operated press for making impressions of fish scales on cellulose acetate. (Photograph by D. W. Kelley.)

This unit, which is controlled by an adjustable thermoregulator, has a heat range from 200° to 600° F. About 250° F. has been found to be a satisfactory working temperature.

OPERATION

The material used for making the impressions is clear cellulose acetate, 0.050-inch thick. No doubt other plastic materials also are adaptable to this work. The cellulose acetate can be cut easily with tin shears; how-

ever, a print-shop paper cutter is faster and produces more nearly uniform slides. The slides usually are cut in the conventional slide size, 1 by 3 inches, or in the size ½ by 3 inches. Numerous firms can supply cellulose acetate in sheets, usually in the stock size of 20 x 50 inches.

Although the plastic can be softened by the application of a solvent, we have found it far more satisfactory to soften the material with heat. In initial experiments the plastic slide was heated before it was inserted in the press. Simpler and speedier operation, and better results, are obtained by incorporating the heating element in the press.

In taking scale samples, the excess mucous, dead skin, and dirt are wiped from the side of the fish before the scales are removed. If this operation is done carefully, no further cleaning of the scales is necessary at the time the impressions are made. Several scales are selected for uniformity and perfection; *i.e.*, regenerated and irregularly shaped scales are not used. With large scales this selection can be made without magnification; if the scales are small a reading glass or wide-field microscope may be used. Next, the scales are arranged on the slide. Since only the sculptured side of the scale will make a readable impression, the scales must be placed with this side next to the slide. With a little practice the operator can distinguish the surfaces of the scale, usually employing the direction of curling as a clue. The slide is then placed on the lower die of the press, and pressure is applied.

The depth and distinctness of the impression can be regulated by changing the temperature, the amount of pressure, or the time the slide is left under pressure. A reasonable amount of experience will enable the operator to find the best combination to obtain good results. Scales of different sizes or species of fish require somewhat different adjustments. An occasional examination of a slide, by means of a microscope or a micro-projector, will show whether clear-cut impressions are being obtained. We have been able, with both of these scale presses, to prepare impressions that are definite and sharp to the very edge of the scale, and hence are suitable for the measurement of scales.

After the slide is taken from the press, the scales are removed from it, leaving only their impressions. The slide is then inserted in the scale envelope, which may then be filed and stored. Ordinary care will prevent the impressions from becoming scratched or otherwise damaged. At room temperature, the material will last indefinitely without discoloration or deterioration.

A few precautions are necessary in the use of the scale press. At times the slide may tend to warp because of heating on only one surface. This warping can be prevented by leaving the two dies in contact for a sufficiently long period of time (for example while selecting scales for the next impression) to warm the lower die. Warping may be averted also by the adjustment of the temperature and of the length of time pressure is exerted or by having a heating unit in each die. A tendency for the slide to stick to the upper die usually indicates that the temperature is too high. If

the two dies become out of line with each other, the slide may show a full impression on only part of the field. The planes of the dies are brought back into parallel in the manual press by adjusting the six nuts that fasten the top plate to the frame bolts and in the electric press by rotating the adjusting plate beneath the lower die.

The scale presses described here are experimental in that they represent the embodiment of various successive ideas in design. They produce excellent results; but, as with any such mechanical device, there is room for refinement and improvement. One desirable feature might be the heating of both die plates; this change, however, might have the disadvantage of offering further opportunity for burning the operator's fingers. Another suggestion is that compressed air rather than a hydraulic jack could be used as a source of pressure, with considerable increase in the speed of operation. Finally, it might be possible to devise a more satisfactory method of keeping the die surfaces parallel.

MANAGEMENT OF FLORIDA'S FRESH-WATER FISHERIES

John F. Dequine

Game and Fresh Water Fish Commission
Tallahassee, Florida

Abstract

Recreational fishing contributes a substantial amount to Florida's economy. A variety of game and rough fishes of which the more important are listed, make up the catch.

Commercial fishing operations, practically eliminated in 1946, are being resumed as detailed studies show the effect of such exploitation on total fish populations. Further investigations are under way to determine the best utilization of fishery resources, consistent with the maintenance of a high degree of success by sport fishermen.

Extent and Types of Inland Waters

Florida has an abundance of fresh-water lakes and streams, all of which produce fish in quantity. The inland water area of 4,298 square miles includes some 30,000 named lakes (Irvine, 1948). This large water area, combined with rapid growth rate of the fishes makes Florida perhaps the greatest potential producer of fresh-water fish in the nation. Most of the waters are shallow—less than 20 feet in maximum depth. Bottoms vary from the heavy muck types found in the Everglades to the pure-white sand of the lakes in the central part of the state. Fish production also varies greatly; population determinations made through the use of rotenone have shown variations from 22 pounds (Meehean, 1942) to 863 pounds (H. R. Bissland, unpublished data) per acre in natural waters. General observations correlate the sand-bottom lakes with low and the muck-bottom waters with high total production.

Important Fresh-Water Species

A great deal of work remains to be done on the taxonomy of the fresh-water fishes, especially as concerns subspecies. For that reason, subspecific names are omitted where, in the writer's opinion, a reasonable doubt concerning their validity is justified. The list is not intended as a check-list, but rather as an inventory of those species contributing materially to the sport or commercial catch. The designation of species as "Game fish" and "Rough fish" follows the Rules and Regulations of the Florida Game and Fresh Water Fish Commission. Common and scientific names are those accepted by the American Fisheries Society (1948).

Game fish.—Chain pickerel (*Esox niger*), redfin pickerel (*Esox americanus*), black basses (*Micropterus* spp.), spotted sunfish (*Lepomis punctatus*), yellowbelly sunfish (*Lepomis auritus*), longear sunfish (*Lepomis megalotis*), bluegill sunfish (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), warmouth (*Chaenobryttus coronarius*), and black crappie (*Pomoxis nigro-maculatus*).

Rough fish.—Longnose gar (*Lepisosteus osseus*), spotted gar (*Lepisosteus productus*), Florida gar (*Lepisosteus platyrhincus*), bowfin (*Amia calva*), gizzard shad (*Dorosoma cepedianum*), lake chubsucker (*Erimyzon sucetta*), southern channel catfish (*Ictalurus lacustris punctatus*), white catfish (*Ictalurus catus*), yellow bullhead (*Ameiurus natalis*), speckled bullhead (*Ameiurus nebulosus marmoratus*), and flat bullhead (*Ameiurus platycephalus*).

Economic Value of Recreational Fishing

A questionnaire sent out by the writer in 1947 to license-buying sport fishermen indicated a hook-and-line catch of 26 million pounds of fresh-water fish for that year. As licenses are required only of non-residents, residents using rod and reel, and residents outside of their home county, a conservative estimate of the total catch would place it at double that taken by licensed fishermen, or approximately 50 million pounds. If the figure of $2.00 per pound placed on warm-water game fish by the River Basin Studies Unit of the U. S. Fish and Wildlife Service is applicable, the catch for 1947 indicates an expenditure of 100 million dollars for recreational fresh-water fishing. Other "surveys" by chambers of commerce, newspapers, and the Florida Wildlife Federation place this figure as high as 250 million dollars per year. Recreational fishing contributes a substantial amount to Florida's economy, regardless of whose figures are used.

History and Importance of Commercial Fishing

Commercial fishing activities on a large scale have been practiced in Florida's fresh waters since before 1890, and at some time have included all of the species listed above. A mixture of sunfishes, commonly termed "bream," black crappie, black bass, and the catfishes and bullheads have been the most important species.

Although the bream, crappie, and black bass have been protected over most of the state for about 25 years, two bodies of water were exempted from laws covering the rest of the state. These exceptions were Lake Okeechobee and the northern half of the St. Johns River, including Lake George. These waters, because of their great area and production and the presence of marine species at certain seasons, were classed as "salt waters" for purposes of administration, and thus came under the jurisdiction of that state agency having responsibility for the salt-water fisheries. In 1935, legislative action was taken to exclude the black bass from the commercial

list in these waters. In 1946, the Game and Fresh Water Fish Commission [1] promulgated rules which prohibited the sale of any fresh-water game fish. A round of legal battles followed, with a final decision in January 1948 to the effect that the Commission had unqualified authority to control methods of capture and sale and to regulate fresh-water fish in anyway. Laws already in effect in other waters prohibiting the use of wire traps or pots, pounds, and seines or nets of any kind were then applied to Lake Okeechobee and the St. Johns River. Since that Supreme Court decision, the legal sale of all fishes listed as "Game fish" has been prohibited.

The principle methods of taking commercial species before 1946 were haul seines up to 4,500 yards long, wire pots or traps, trot-lines, pound nets, and a few hoop nets. Stationary and drifting gill and trammel nets set to take transient salt-water species incidentally captured some fresh-water fish. The Commission's action in 1946 prohibited the use of all of this gear except trot-lines.

The economic effects of this action were pronounced in the communities around Lake Okeechobee and the lower St. Johns River. An estimated 2,500 persons were directly or indirectly dependent upon the fishing industry, which, according to the best records available, had in 1945 a total catch of roughly 1,500,000 pounds of bream, 850,000 pounds of crappie, and 4,800,000 pounds of catfish and bullheads valued at approximately $1,541,000 (Marshall, 1946).

Investigation of Management Problems

Since it was obvious to even the most rabid opponents of commercial fishing that the huge potential production of catfish and bullheads could not be harvested adequately by the remaining legal method of trot-lining, it became the task of the writer and his assistants to determine methods that would permit the taking of these species without serious harm to the game fishes. Investigations on the effect of commercial fishing operations and gear upon populations of game fish were instituted on the St. Johns River in June 1947 and on Lake Okeechobee and other large lakes somewhat later.

A series of studies by Commission biologists early this year established that the catch of game fish by baited pound nets and wire traps of certain specifications was less than 7 percent by weight of the total catch, and that the game fishes suffered practically no mortality while confined. Other studies determined that short haul seines used in certain areas of the St. Johns River during the runs of shad (*Alosa sapidissima*) and glut herring (*Pomolobus aestivalis*) took less than 5 percent of game fish by weight of the total catch, all of which could be released unharmed (L. H. Hutchens, unpublished data). On the basis of these findings, recommendations made to the Commission that these operations be permitted resulted in

[1] The present Commission was set up in 1942 as a constitutional body with authority to make rules and regulations affecting seasons, bag limits, method of capture, . . . of fresh-water fish and game animals.

legalizing of the gears in the areas studied, and to a limited extent in other waters with similar characteristics.

Studies of the effect of hoop nets and seines on fish populations in Lake Okeechobee, the St. Johns River, and in other large waters where commercial operations have been prohibited for over 20 years are also under way at present. Those studies are designed primarily: (1) to determine standing fish population, and interrelationships among species; (2) to estimate potential annual yields of food and game fishes and amounts which can be taken without damage to the breeding stock; (3) to ascertain the effect of various types of fishing gear on game and food fishes, with emphasis on determining proper equipment for use by commercial fishermen to harvest the annual crop of food fishes and to control rough fish; (4) to formulate enforceable regulations to benefit spawning conditions and habitat for both game and food fishes; and (5) to obtain accurate records of catches by sport and commercial fishermen.

Although these investigations have not been under way long enough to justify definite conclusions, there are strong indications not only that growth rates are greater in waters where extensive commercial operations have been carried on, but that those waters also have a much higher proportion by weight of preferred game fish than do similar waters that have not been fished commercially for many years.

Conclusion

Florida's chief problem is not one of creating new waters or of increasing productivity, but rather is one of making the best use of present resources. Studies are under way to determine methods of realizing this maximum utilization without injury to the success of sport fishermen. Should the control of rough fish be found to increase the catch by sport fishermen, that control can be carried out by private industry. Economic and esthetic values as well as biological aspects are being considered in drawing up plans for the regulation and management of fresh-water fishery resources in an effort to use those resources for the benefit of all.

Literature Cited

American Fisheries Society
1948. A list of common and scientific names of the better known fishes of the United States and Canada. Am. Fish. Soc., Special Pub. No. 1, 45 pp.

Irvine, E. Eastman
1948. The world almanac and book of facts for 1948. N. Y. World-Telegram, p. 150.

Marshall, Nelson
1946. Preliminary investigations on the effect of commercial fishing on game fish in Lake Okeechobee and the St. Johns River. Univ. of Miami, Mar. Lab., 19 pp. [Mimeographed].

Meehean, O. L.
1942. Fish populations of five Florida lakes. Trans. Am. Fish. Soc., Vol. 71 (1941), pp. 184–194.

THE FISHERY DEVELOPMENT PROGRAM IN THE LOWER COLUMBIA RIVER

Leo L. Laythe

U. S. Department of the Interior, Fish and Wildlife Service
Portland, Oregon

Abstract

The gradual decline of the Columbia River salmon fishery has been brought about through deforestation, pollution, over-fishing, unscreened water diversions, and construction of dams within the watershed. The latter is believed to be the major contributing factor.

Present water-development programs of the U. S. Bureau of Reclamation and the Corps of Engineers have accelerated the organization of a conservation plan for the maintenance of the salmon and steelhead fishery before the proposed dams bring about further diminution of the runs. This plan, endorsed and supported by federal planning agencies, consists of the maximum development and management of the fish runs in tributaries of the lower Columbia River basin. To effectuate this program approximately a 10-year period and 20 million dollars will be required, of which one million dollars have been appropriated for expenditure in fiscal year 1949. Essentially, the program is based on the cooperative efforts of the States of Oregon and Washington and the U. S. Fish and Wildlife Service in (1) removal of obstructions to permit passage of fish, (2) abatement of pollution, (3) screening of water diversions and construction of fishways, (4) transplantation of upriver runs, (5) extension of artificial propagation, and (6) establishment of fish refuges in which conflicting developments would not be permitted. There is sufficient reason to believe that with the effectuation of this program, the populations of salmon and trout in the Columbia River and its tributaries can be maintained.

Introduction

The Pacific Northwest is just entering upon full production through the development of the many resources of the Columbia River basin. Outstanding among the developments in the region is the commercial exploitation of Columbia River salmon which began early in the 19th century at the time of the first white settlements. Previously the Indians had taken large quantities by means of their crude gear. It is estimated roughly that this early Indian fishery may have yielded as much as 18 million pounds of salmon annually.

The first commercial export of Columbia River salmon began in 1830 and during the years that followed, many vessels sailed out of the Columbia River with salted salmon. These vessels delivering their cargoes to ports of the United States, England, South America, the Hawaiian Islands, and China gave early world-wide distribution to the highly-prized Columbia River salmon. In 1866 the first salmon cannery was established on the

river. Demand for this product brought about a rapid increase in production until a peak catch of nearly 43 million pounds was handled by 39 canneries in 1883. Since its beginning, the commercial harvest of salmon has produced in excess of a billion dollars of wealth.

Decline of the Salmon and Steelhead Trout Fishery

In early days the spring run of the king salmon (*Oncorhynchus tschawytscha*) was practically the only Columbia River salmon taken for the market, but as the demand increased, and the king salmon became less abundant, the commercial fishery was extended to include the fall runs of king salmon, red salmon (*O. nerka*), chum salmon (*O. keta*), silver salmon (*O. kisutch*), and steelhead trout (*Salmo gairdnerii*). Although the catch of these species was first recorded in 1889, small amounts probably were caught earlier and included with the catch of the spring run of king salmon. The gradual but persistent decline of the spring run of the king salmon has continued until at present they comprise about 17 percent of the average catch in the river.

The decline in the commercial production of salmon, particularly of the choice red and the silver salmon, has occurred since 1883. Today the average annual production of all species of salmon and steelhead trout in the commercial, Indian, and sport fisheries amounts to approximately 32 million pounds, valued at $17,400,000 (Table 1).

Table 1.—*Average annual yield of the Columbia River fishery, 1938–1947*

Type of Fishery	Catch (pounds)	Value[1]
Commercial (includes trolling)		
Red salmon	278,000	$ 181,000
King salmon	21,968,000	11,203,000
Chum salmon	1,818,000	400,000
Silver salmon	2,402,000	1,057,000
Steelhead trout	1,983,000	853,000
Indian subsistence	1,281,000	240,000
Sport	2,000,000	3,500,000
Total	31,730,000	$17,434,000

[1] Commercial values are given at primary wholesale level of 1947

The encroachment of civilization into the Pacific Northwest can be largely blamed for the decline of Columbia River salmon. In a manner that somewhat parallels the diminution of many species of indigenous animals, salmon have decreased along a trend that it has often been feared might approach extinction. Concerted management efforts on the part of state and federal fishery agencies, however, have prevented their extinction and the fishery has been maintained, although at a reduced level.

Among the many factors contributing to the decline of the fishery are deforestation, stream pollution, commercial exploitation, and the construc-

tion of dams. The lumbering industry was one of the first and more serious offenders. Neglected log jams and splash dams have been an obstacle to the migrations of salmon. Deforestation of the mountains has led to increased spring runoffs, the scouring of stream beds, increased turbidity, and decreased summer flows. Beyond these effects, the lumber and pulp mills have introduced serious pollution in the rivers. Mining also has had deleterious effects on the salmon populations of many tributaries. Tailings have polluted the streams, and in some areas, gold dredging has completely destroyed natural habitats and blocked migrations. Notable examples of the results of mining operations are evident in the Clearwater and Boise River basins where former large runs of salmon have been depleted or completely lost. Factories, canneries, and mills have contributed enormously to the pollution problem by discharging wastes of high oxygen demand as well as those of a toxic nature into the rivers. The pollution problem has been futher intensified by domestic wastes, where large centers of population have developed along river banks. The fishing industry itself, without doubt, has been another serious offender with its overexploitation and lack of proper management in early days. Irrigation and power diversions have taken a heavy toll of seaward migrants. Of all factors causing decreases of salmon runs, dams have presented the greatest single obstacle that confronts the maintenance of the fishery resource.

Over 300 dams have been built in the Columbia Basin up to the present time. They vary in size from small irrigation diversion dams to such huge structures as Bonneville Dam and Grand Coulee Dam (Figs. 1, 2, and 3). Yet, in the construction of only a few was any thought given to their effect on fish. The present trend is toward greater development of the water resources of the basin, and elaborate plans have been made by such construction agencies as the Corps of Engineers, the Bureau of Reclamation, and private power companies for continued expansion for many years to come. McNary Dam on the Columbia River and Detroit and Meridian Dams in the Willamette Basin are under construction. They will undoubtedly be followed by other large projects, such as the authorized Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams on the lower Snake River and such significant proposed dams as Priest Rapids, John Day, and The Dalles on the Columbia River and Hells Canyon on the Snake River.

Dams have presented many serious problems to both adult and young anadromous fish. Early construction of even low dams seldom took into consideration the need of fish passages, and such fishways, when installed, were usually unsatisfactory; therefore, many miles of spawning area have become unavailable to the salmon. For example, the red salmon which requires residence in a lake as a part of its early life history, has become greatly restricted in range. Black Canyon Dam on the Payette River completely severed the Payette Lakes from the large run of red salmon that spawned in that watershed. Many lakes have been cut off in a similar manner in other areas. At the same time, other species of salmon have, through man's developments in the basin, suffered as much. Notable

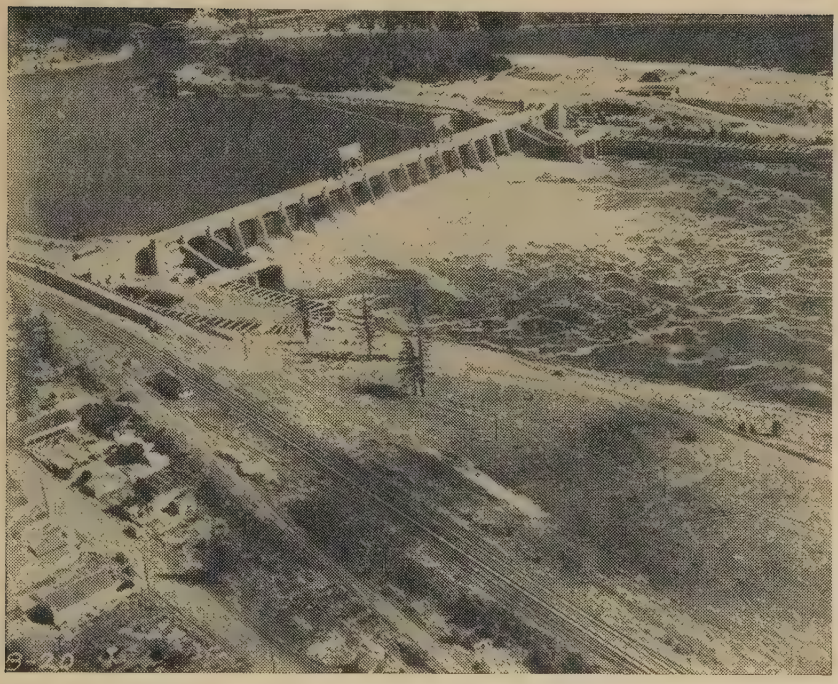

FIGURE 1.—Spillway section of the Bonneville Dam. The Washington shore fishway is visible at left center, and part of the Bradford Island fishway can be seen at upper right. (Photograph, courtesy of Corps of Engineers.)

examples are the large runs of king salmon that were abruptly cut off by a large power dam in the Lewis River, Washington, and the king salmon that were annihilated by Warm Springs Dam in the Malheur River, Oregon. These examples are typical in the history of basin developments where two-thirds of the original spawning area has been lost.

Although the many dams on tributaries of the Columbia River have greatly reduced the salmon population over the past three-quarters of a century, at present only three dams span the Columbia River itself from its mouth to the Canadian border; namely, Bonneville, Rock Island, and Grand Coulee. A fourth, McNary Dam, is under construction and is scheduled for early completion.

Bonneville Dam, located about 145 miles upstream from the Pacific Ocean, was completed in 1938. During the construction of Bonneville Dam elaborate fish-passage facilities were incorporated in the structure at a cost reportedly in the neighborhood of 7 million dollars. The facilities have successfully provided the upstream migrants means of passing the dam, either by fish ladders or fish locks.

Rock Island Dam, constructed about 1930 by a private utilities company,

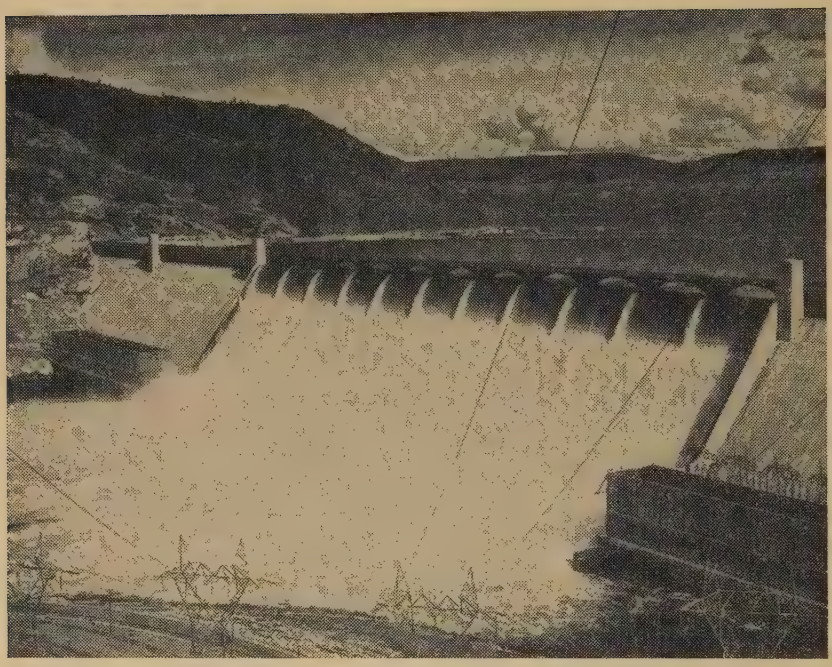

FIGURE 2.—Spillway section of Grand Coulee Dam, a permanent barrier to upstream migration of anadromous fishes. (Photograph, courtesy of Bureau of Reclamation.)

is a low-head structure located approximately 453 miles upstream and is equipped with fish-passage facilities.

The world's largest dam, Grand Coulee, was completed in 1942 and has blocked all upstream migrations of fish at a point approximately 596 miles above the mouth of the river. Because of the height of the dam and the difficulty of safely passing young seaward migrants, it was deemed impracticable to install facilities for handling fish at this structure.

Bonneville and Grand Coulee Dams marked the advent of a new era in the management of the anadromous fish of the Columbia River. The fish ladders and locks constructed in Bonneville Dam permitted for the first time the taking of a census of the adult upstream migrants of salmon in this reach of the river. As a result of findings at Bonneville and Grand Coulee Dams, special recognition has been given by construction agencies to the problems involved in maintaining this resource in conjunction with water developments within the basin.

As the Grand Coulee project developed and construction of the dam became imminent, plans were made to preserve as much of the runs as possible. In 1938 a specially organized board of consultants, consisting of leaders in the fields of fisheries, economics, and engineering, studied the

problem and agreed upon the procedures and policies to be followed. As a result all salmon and steelhead trout of the upper Columbia River were trapped at Rock Island Dam from 1939 through 1943, and transferred to chosen streams and newly erected hatcheries situated below Grand Coulee Dam. The entire program can be considered somewhat in the nature of an

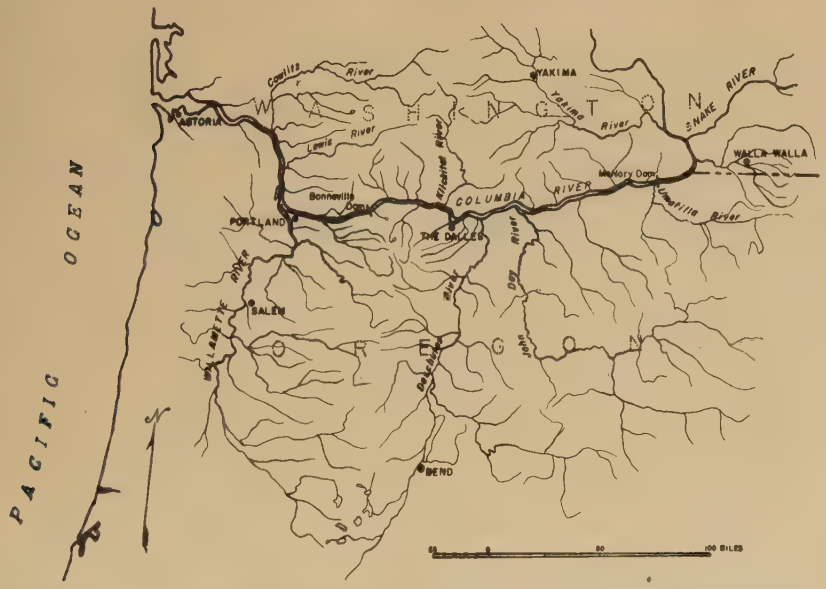

FIGURE 3.—Lower Columbia River basin, where salmon rehabilitation will be concentrated.

experiment that provided sufficiently promising results to warrant similar operations in the face of such a problem elsewhere. A summary of data collected at fish-counting stations at Rock Island fishways shows that runs of king salmon have persisted at approximately the same level and that the red salmon have increased considerably since these operations began. The average annual runs for the two species of salmon and for steelhead trout have been as follows:

Years	*King Salmon*	*Red Salmon*	*Steelhead*
1933 to 1943	8,058	17,006	3,137
1944 to 1947 (after transfers).	7,695	34,146	1,533

Admittedly, much variation can be expected in natural populations as a result of normal fluctuations in environmental conditions, either in fresh

water or in the ocean, and many extremes can be encountered. Nevertheless, there has not been an obvious downward trend in the chinook and red salmon runs that were involved in the Grand Coulee operations.

The Organization of a Management Program

In 1938, Congress authorized the appropriation of $500,000 for surveys and improvements in the Columbia River watershed for the benefit of salmon and other anadromous fish (Public Law 502, 75th Congress). This authorization recognized that during the period of 1905 to 1931, inclusive, the Government had received more than $500,000 from the lease of seining grounds on Sand Island and Peacock Spit at the mouth of the Columbia River and, further, that because of the destruction of favorable environmental conditions by deforestation, pollution, dams for hydroelectric development, and diversion of water for irrigation, the salmon fishery of the Columbia River was in a serious and progressive decline. The purpose of this authorization was to reinvest the funds derived from the fisheries back into that resource.

With the limited appropriations that resulted, studies were begun of the streams that remained accessible to salmon. A program of stream census and surveys was inaugurated by the Fish and Wildlife Service to provide information on the value of all tributaries of the Columbia River utilized by salmon and on limiting features such as falls and log jams. Although not completed, this program was carried far enough to culminate in plans for improvement that would permit greater utilization of the streams.

On August 8, 1946, the President approved a congressional amendment (Public Law No. 676, 79th Congress) to the Act of May 11, 1938, which removed the limitation on subsequent appropriations to be made by Congress for the development of the fisheries for anadromous species in the Columbia Basin. It enabled and authorized the Secretary of the Interior to utilize the facilities and services of the conservation agencies of the States of Idaho, Oregon, and Washington in developing the salmon resources of the Columbia Basin. The Act was an important step in the history of salmon conservation because it permitted closer cooperation between the Federal Government and the States and also permitted the transfer of monies to the States for specific work—an advantage that had not been previously authorized.

Intensive planning of water-development projects in the last few years has pointed to the need for a definite program of conservation, which would have as a goal the preservation of the fishery of the Columbia River. Dams such as McNary, Priest Rapids, and those on the Snake River have clearly indicated that the lower Columbia Basin is obviously the region in which to concentrate efforts toward maximum utilization of streams by fish. Man-made and natural obstacles have reduced the runs of many of these tributories to a small part of their apparent capacity and much improvement is needed to make them wholly available. Waterfalls should

be made passable by means of fishways; improved fishways should be constructed over some existing dams; log jams, splash dams, and beaver dams should be removed; hatcheries should be added to supplement natural propagation; and continued studies are necessary to develop the best means of managing the fishery. Such a plan for the development of the lower Columbia Basin was organized by the Fish and Wildlife Service and the States of Oregon and Washington as a program for restitution of losses incurred in the past.

At the occasion of a hearing in Walla Walla, Washington, (June 25 and 26, 1947) the Columbia Basin Inter-Agency Committee, consisting of agencies concerned with the water-development projects of the basin, publicly heard the fishery interests expound the seriousness of the fish-migration problem. Careful study was given the problem through the aid of fact-finding subcommittees, and, as a result, all agencies, both federal and state, recognized that every effort should be put forth by the Federal Government to maintain the salmon fishery of the Columbia and its tributaries at the highest possible level of abundance, concurrent with the development of the other natural resources of the basin. In the face of existing demands for hydroelectric power and flood control, a temporary cessation of dam construction requested by fishery interests was not deemed advisable, but speedy action was suggested to prevent further losses to the fishery. In formal action, the Columbia Basin Inter-Agency Committee accepted and recommended the Lower Columbia River Fishery Development Program as the best means of maintaining the fishery. Subsequently, the Federal River Basin Inter-Agency Committee likewise announced publicly its acceptance and endorsement of the program.

The Corps of Engineers incorporated this same program of salmon development into a basin-wide comprehensive plan, and included it in the recent *Review Report on the Columbia River and Tributaries.* Subsequently, the Bureau of Reclamation and the Corps jointly recommended it in their coordinated program. The Corps of Engineers submitted a request to Congress for an initial appropriation in fiscal year 1949 to inaugurate the work. A similar item was carried in the 1950 fiscal year budget. The 80th Congress recognized the situation and appropriated approximately a million dollars to initiate the program in fiscal year 1949. As a result there came into being a concerted program for the development of the salmon and steelhead trout in the lower Columbia River watershed.

The Plan of Development

The presently stated objective of the Lower Columbia River Fishery Development Program is the maintenance of the runs of anadromous species supporting the commercial and sport fisheries at the highest possible level of abundance. It is hoped that the fishery can be maintained at somewhat near the present level of production. It is possible that this goal cannot be achieved but, on the other hand, it is conceivable that it may be exceeded.

Initial estimates indicate that the construction phase of the program will cost approximately 20 million dollars and require 10 years to complete. Thereafter, it is estimated that approximately $1,250,000 will be expended annually for maintenance and operation of the plan to achieve the desired optimum production of salmon and steelhead.

In view of the fact that recommendations of the Columbia Basin Inter-Agency Committee considered that the fishery-development program would be concurrent with dam construction, the 10-year period originally proposed was closely coordinated with the schedule of water-development projects. The original recommendation provided for inauguration of the work in fiscal year 1948; however, no appropriations were available until the following year. This delay in appropriations for fishery development has not been accompanied by an equal delay in dam construction. Consequently, the same amount of work must be completed by the end of the original 10-year period, *i.e.,* 1957. The first year's appropriations were about one-third the amount programmed. The amount being considered by Congress for fiscal year 1950 is likewise about one-third the original request. As a result, the work must be intensified if the original schedule is to be reached and maintained. Also, successive appropriations should be increased to compensate for time lost. The program is so organized that the first beneficial effects probably will not be noticed until near the end of the 10-year period and any lengthy delays in the early stages may prove ruinous.

Inasmuch as the fishery-development program is financed by the Federal Government, the funds appropriated are transferred to the Fish and Wildlife Service by the Corps of Engineers for expenditure as budgeted. The Service is accountable in much the same manner as in the distribution of funds under the Pittman-Robertson Act. Through close cooperation of Oregon, and Washington with the Fish and Wildlife Service, the funds are reallocated in amounts proportionate to the activities planned. The States of Oregon and Washington are responsible for the construction of all projects they recommend in their areas. The Fish and Wildlife Service will construct and enlarge a small number of hatcheries located in Oregon and Washington. All authorized projects are under the review and inspection of the Fish and Wildlife Service. At the conclusion of construction, all facilities will be managed and operated by the separate agencies.

Management is the prime operating principal of the program. Presumably, research in past years has been sufficient to permit the formulation of satisfactory recommendations and management policies. The intent of Congress is that investigations must be limited to those directly associated with management and the development of management policies. Nevertheless, it is agreed that additional continuing studies are needed, and it is regrettable that the present program cannot finance them. Fishery research in the Columbia Basin will be carried on as usual in regularly established programs by the States and the Fish and Wildlife Service. Many of these investigations will undoubtedly be directed toward questions that might be

confronted in the management of the fisheries, and, furthermore the Lower Columbia River Fishery Development Program will make requests of research institutions when particular problems require intensive investigations for solution. Such close cooperation in research activities is essential.

To execute the objective of this fishery program the following phases of operation are designated: (1) removal of obstructions to permit passage of fish; (2) abatement of pollution; (3) screening of water diversions and constructions of fishways; (4) transplantation of upriver runs; (5) expansion of artificial propagation; and (6) establishment of fish refuges in which conflicting developments will not be permitted.

Removal of obstructions.—The value of the lower Columbia tributaries can be greatly increased by the removal or correction of both natural and artificial obstructions such as dams, log jams and falls. Vast areas of excellent spawning and rearing grounds are not accessible because of such obstructions.

Abatement of pollution.—Pollution has become, without doubt, one of the greatest problems in the maintenance of salmon runs, especially in the Willamette River system. The problem, however, is not without solution; in fact, material aid appears to be within sight. In lower stretches of the Willamette the pollution load is so heavy during the summer and fall that the oxygen content of the water is insufficient for fish life. As a result all fish runs which formerly migrated through the lower Willamette during the summer months have been exterminated. If pollution can be reduced to the point where it is no longer an obstacle, the production of salmon and trout in the Willamette River can be increased tremendously. Estimates of the Oregon Fish Commission indicate its capacity to be in the neighborhood of five times the present production. Pollution is perhaps the greatest hindrance to this utilization.

In Oregon and Washington, active sanitary commissions are meeting the problem in a commendable manner. Industry is attempting to devise means of discharging effluents without damaging the quality of the water. The cities, likewise, are installing adequate sewage treatment plants. The presently inaugurated program of the U. S. Public Health Service, in cooperation with the States, will undoubtedly do much to alleviate the situation by coordinating efforts and making additional funds available. Any work conducted in the salmon-development program will be closely coordinated with and will take full advantage of all activities of the States and the Public Health Service.

Screening or water diversions.—In view of the tremendous loss of fingerlings in diversion canals, it is imperative that an extensive screening program accompany the improvement of all tributaries. At the present time irrigation demands have resulted in a myriad of diversion canals of all sizes, most of them without any protection for fish.

The value of fish screens was demonstrated forcibly by a recent incident at Tumwater Dam on the Wenatchee River. For several days in May 1948, screens in the power diversion were removed for emergency repair.

Observations of seaward-migrating red salmon during this period indicated a mortality of several thousand fingerlings that passed through the unprotected penstocks and turbines. On one day 1,200 to 1,500 dead fingerlings were found below the power house. Other examples can be cited where the losses have been many times greater because of unscreened water diversions.

This situation has been remedied considerably by the progressive screening programs of the States of Oregon and Washington, but their efforts must be aided and intensified in order to meet the schedule that is sought.

Construction of fishways.—Some 75 falls (Table 2) are known to need improvement in the lower tributaries. Most of them are of such magnitude

TABLE 2.—*Natural stream barriers requiring improvement in the lower Columbia River basin*

Stream	Number of falls
Oregon	
Clatskanie River	1
Hood River	1
Little Fall Creek	2
Little North Santiam River	1
Molalla River	1
Scappoose Creek	1
Willamette River	1
Washington	
Abernathy Creek	2
Arkansas Creek	3
Bear Creek	1
Butter Creek	1
Cedar Creek	1
Cispus River	1
Coldwater Creek	2
Coweman River	3
Cowlitz River	2
East Fork, Lewis River	11
Grays River	2
Green River	2
Kalama River	1
Klickitat River	5
McCloskey Creek	1
Mill Creek (Tributary of Columbia River)	1
Mill Creek (Tributary of Cowlitz River)	1
Niggerhead Creek	1
Nineteen Creek	1
North Fork, Cispus River	1
North Fork, Tilton River	2
Olequa Creek	1
Ostrander Creek	2
Skate Creek	1
Stebbins Creek	1
Washougal River	10
West Fork, Washougal River	1
Wind River	6

that ladders will have to be installed to insure proper passage of migrating fish. The construction work of some will be elaborate, but, generally, the distances to be improved involve heights of less than 25 feet. Ladders on these falls will make available many hundreds of miles of spawning area that are not now utilized.

Transplantation of upriver runs.—Fundamentally the transplantation of upriver runs would be similar to the relocation of salmon in the Grand Coulee salvage program. It would, however, be on a far greater scale, especially if additional dams in the main stem of the Columbia and its principal tributary, the Snake River, prove to be effective barriers to the migration of spawning fish. In spite of the indicated success at Grand Coulee it is realized that other transplantations may present greater problems and may even be complete failures. Transfer or restoration of the spring runs of king salmon will probably present the greatest problem. The intent is not to move all upriver fish to the lower tributaries, but rather to build up the existing runs in the lower basin to the maximum capacity of the streams utilized. Many streams, however, contain no salmon at all and stock may have to be obtained from upper tributaries. These transfers will be carried out, at first on an experimental scale and later, on an intensified and productive basis.

Expansion of artificial propagation.—Artificial propagation will play an important role in supplementing natural production, and in places hatcheries may even be the source of entire runs. The Spring Creek Hatchery of the Fish and Wildlife Service and the Oxbow Hatchery of the State of Oregon, are examples of what can be done when adequate natural habitat is lacking. Since the Spring Creek Hatchery was constructed in 1897–1898, a run has been built to some 10,000 adult fish which return annually to ponds supplied by a spring of approximately 5 second-feet of water. This spring was never utilized by salmon prior to the construction of the hatchery. The estimated minimum hatchery requirement of the salmon rehabilitation program includes the construction, relocation, or expansion of hatcheries on the following streams:

Oregon	*Washington*
Clackamas River	Abernathy Creek
Eagle Creek	Coweman River
Herman Creek	Cowlitz River
Hood River	Deep River
John Day River	Elockomin River
Klaskanine River	Grays River
Metolius River	Husum Springs
Molalla River	Kalama River
Sandy River	Klickitat River
Tanner Creek	Little White Salmon River

Oregon (Cont.)
Tillasqua River
Warm Springs River

Washington (Cont.)
Monahan Creek
Skamokawa River
Spring Creek
Toutle River
Washougal River
Wind River

Establishment of fish refuges.—Many of the important tributaries of the lower Columbia and Willamette Rivers should be managed exclusively for the maintenance of salmon and steelhead runs, and no conflicting development should be permitted. The belief of state officials in the principle of fish refuges has been made evident by actions of the legislatures during this past year. The State of Washington enacted a law which sets aside all tributaries of the Columbia River below McNary Dam, with the exception of North Fork of Lewis River and the Big White Salmon River, as refuge streams for the primary function of propagating anadromous fish. The State of Oregon has passed similar legislation covering the following rivers: Lewis and Clark, Klaskanine, Clatskanie, Tillasqua, Scappoose and many smaller streams.

Besides the streams legally set aside as fish refuges, the following in Oregon should also be designated and recognized as such:

Bear Creek
Big Creek
Clackamas River
Deschutes River
Gnat Creek
Green River
Hood River
John Day River
McNulty Creek
Milton Creek
Molalla River
Plympton Creek
Tide Creek
Youngs River

Many of these refuge streams are of considerable significance for other purposes. They are, in effect, some of the most important tributaries of the lower river, as for example, the Cowlitz, the Klickitat, and the Deschutes, but they also have enormous potentials for the production of salmon. Existing power projects would not be eliminated under the program of development but their operation and construction would need be modified and coordinated with the fishery program to reduce the present interference. Furthermore, any additional power development on these streams should be prohibited.

Current progress.—During the first year of operation, plans have been drafted and construction begun on Sandy Hatchery in Oregon and the Klickitat and Spring Creek salmon hatcheries in Washington. Stream gauges and thermographs have been installed on several streams. Fishways

are being constructed at three major falls. Various other obstructions are being cleared from tributaries in Oregon and Washington.

Conclusions

Experience and past studies indicate that the objectives of the Lower Columbia River Fishery Development Program can be attained. If continued support, cooperation, and collaboration can be assured by State and Federal development agencies, as well as by private and public utilities throughout the progress of the program, there is reason to believe the anadromous salmon and steelhead trout populations in the Columbia River and its tributaries can be maintained at a satisfactory level.

A CONTRIBUTION TO THE ETIOLOGY OF ULCER DISEASE OF TROUT

S. F. Snieszko and S. B. Friddle

U. S. Department of the Interior, Fish and Wildlife Service
Kearneysville, West Virginia

Abstract

During the fall of 1947 and the late summer of 1948, outbreaks of ulcer disease occurred among brook trout fingerlings at the Leetown station and other hatcheries. From the ulcers, blood, and kidneys of the diseased trout were isolated bacteria which could be successfully cultivated only on media to which blood or fish-tissue extract had been added. Some characteristics of these bacteria are described.

In a series of inoculation experiments, brook, brown, and rainbow trout were infected with pure cultures of the isolated bacteria. When the trout used for these tests were free from a latent infection of *B. salmonicida,* ulcer disease could be reproduced and the bacteria reisolated in pure culture from the inoculated fish. On the basis of the information on hand, it is believed that the isolated bacteria belong to the genus *Hemophilus.*

Introduction

Ulcer disease is common among trout. The brook trout, *Salvelinus fontinalis,* seems to be particularly susceptible. Calkins gave the first account of this disease, but in the light of the excellent investigations of Fish (1934) and Wolf (1939) it appears that the epizootic described by Calkins (1899) was complicated by an infection with a protozoan. Fish discussed the symptoms in detail, and Wolf studied the mechanism of infection and transmission of this disease. On the basis of the detailed description of the symptoms of ulcer disease, the authors are inclined to believe that outbreaks of an infection reported by Reed and Toner (1942) might be related to a fish septicaemia said by Schäperclaus (1941) to be caused by a bacterium most likely identical with *Pseudomonas hydrophila.* The uncertainty as to the actual cause of outbreaks reported as ulcer disease, has left the problem of its etiology open to investigation. Consequently, when the opportunity presented itself, we undertook the bacteriological studies, the results of which are reported in this paper.

Preliminary Observations

It is believed desirable to present first a background for the observations on the outbreak of ulcer disease at the Leetown station. Furunculosis was endemic for several years and experiments were in progress on the

prophylaxis of this and other diseases of brook trout.[1] Trout were distributed among six circular pools. They were treated with sulfamerazine, roccal, and a combination of both drugs. Trout in one of the six pools were treated both with roccal and sulfamerazine, and fish in this pool remained free from furunculosis until the end of December, while in other pools this disease appeared in early September. Lesions typical for ulcer disease appeared in all pools simultaneously in November. In bacteriological examination of trout with ulcer disease *B. salmonicida* and other bacteria were regularly isolated. The latter grew as small colonies only on media enriched with blood. From the trout with ulcer disease in the pool in which the fish were treated with sulfamerazine and roccal this new bacterium was regularly isolated in pure culture. Losses were small among trout in this pool, until furunculosis appeared by the end of December, and from this time on trout in this pool suffered from infection with both diseases. This observation showed clearly that ulcer disease existed separately from furunculosis and that it was apparently caused by a different etiological agent.

Description of the Disease and Isolation of the Bacteria

The symptoms of ulcer disease at the Leetown station were exactly the same as described by Fish (1934) and Wolf (1939). At first, small white tufts resembling bunches of mycelium appeared on the surface of the trout. Under these tufts developed small, circular, shallow, red spots, which increased in size. Several spots often coalesced to form a large, irregular lesion. Some of the lesions were disinfected by swabbing gently with alcohol before samples were taken for bacteriological examination. The material was removed from others without any disinfection in order not to destroy any superficially located bacteria. Often, though not regularly, *B. salmonicida* was found in the lesions; more frequently it was present in the kidneys of the diseased fish, especially brook trout.

Small, barely visible colonies developed on agar media prepared with tryptic digest of casein, proteose peptone, yeast extract, or other dehydrated media commonly recommended for the isolation of pathogenes that are difficult to grow. These small colonies grew better if the inoculum contained some blood or crushed tissue. Further isolations, therefore, were made on media to which some rabbit blood or fish extract was added. On these media it was possible to isolate, often in pure culture, the ulcer disease bacteria which grew as small, discrete colonies.

Methods of Cultivation

Although repeated tests indicated that the bacterium isolated from brook trout with ulcer disease grew well in media to which either fresh rabbit blood or extract from trout tissues was added, the latter proved

[1] Results will be reported at a later date.

more convenient and now is used regularly in our laboratory. Since the addition of trout-tissue extract may prove useful to other workers, a brief description of the method of its preparation is given in the following paragraph.

The tissue extract should be prepared from normal healthy trout. The head, fins, and internal organs are removed and the blood is collected and hemolysed in distilled water. To one part (by weight) of fish tissue, two parts of water are added and the combination is ground in a Waring Blender for 5 minutes. The suspension is centrifuged first alone and then with diatomaceous earth, and is then frozen overnight. It is better to use fish which have not been fed during the last 24 hours. The next day the extract is thawed, and centrifuged again, and the supernatant, nearly a clear liquid, is sterilized by filtration. Sterile extract is stored in a refrigerator. The addition of 3 to 4 percent of this extract to media insures good growth of the bacteria isolated from ulcer disease. The standard basic medium which is used with success in our work contains 5 grams per liter of each of the following components: proteose peptone No. 3; tryptic digest of casein; yeast extract; maltose; and sodium chloride. The pH of the medium is adjusted to 7.0. Maltose is used as a source of carbon because it is utilized by these bacteria, and the production of acid from it is slow.

Characteristics of the Isolated Bacteria

Morphology.—Bacteria appear in the lesions, kidneys, and blood and on culture media as small (1.0-2.0 by 0.6-0.8 microns), gram negative, nonmotile rods. They occur singly, in pairs, or sometimes in short chains.

Growth requirements.—Good growth in successive transfers was obtained only on media with the addition of blood or trout-tissue extract unheated and sterilized by filtration. The addition of Difco hemoglobin had no effect. No visible growth was obtained in any of the dehydrated, commercial media recommended for the cultivation of fastidious bacteria. This microorganism grows well under aerobic conditions at 20–25° C.

Growth characteristics.—On agar slants and plates the bacteria produce small, circular, convex, dull, creamy-gray colonies, which are about 1 millimeter in diameter. The colonies are so compact that when transfers are made entire colonies usually are lifted from the surface of the medium. In liquid media the microorganism generally grows in the form of small floccules which adhere to test-tube walls, or collect as sediment. Usually the bulk of the medium remains clear. Pellicle and ring are often formed. Gelatin with trout extract is not liquefied and litmus milk is not changed. Tests for nitrate reduction and production of indole were negative. Some hydrogen-sulfide production was detected with lead-acetate paper. Beta type of hemolysis was observed in the media with erythrocytes.

The fermentation characteristics were tested in the standard medium with fish extract, chlorphenol-red indicator, and various fermentable substances; these were added to the medium in 1-percent quantities. No

production of gas was detected with any of the substances tested. Media with glucose, levulose, and sucrose were strongly acidified. Slightly acidified were media with xylose, d-mannose, d-galactose, maltose, and cellobiose. No change of pH was noted in media with arabinose, lactose, raffinose, inulin, and mannitol. Fastest and most abundant growth was in media with easily fermented sugars. With the slowly fermented sugars pellicle and ring were produced. In media with readily utilized sugars, but without fish extract, there was only a trace of growth.

On the basis of the characteristics of these bacteria isolated from brook trout with ulcer disease it is believed that they can be classified tentatively as belonging to the genus *Hemophilus* (Bergey's Manual, 1948).

Experiments on the Inoculation of Trout

In order to test the pathogenicity of these bacteria, brook trout, brown trout (*Salmo trutta*), and rainbow trout (*Salmo gairdnerii*) fingerlings and yearlings were inoculated on several occasions. These tests became complicated because furunculosis is endemic at the Leetown station, and lots of brook trout and brown trout used in these tests had a latent infection with *B. salmonicida.*

In the first experiment, brook, brown, and rainbow trout yearlings were distributed among experimental troughs and infected by intraperitoneal or subcutaneous inoculation with the bacteria believed to cause ulcer disease. Most of the inoculated trout died within a week (Table 1; Fig. 1). Some of the dead trout were examined bacteriologically. Bacteria producing the characteristic small colonies of the ulcer-disease microorganism were isolated in pure culture from 12 of 13 rainbow trout, which were examined bacteriologically. From the remaining trout *B. salmonicida* was isolated instead. *B. salmonicida* was isolated from 13 of 14 brook trout examined bacteriologically, whereas the bacteria used for inoculation were recovered only once. About the same results were obtained with brown trout as with brook trout. This experiment indicated that whenever trout were originally infected with *B. salmonicida,* furunculosis became acute after the introduction of another pathogen.

In the second inoculation experiment yearlings of the same three species of trout were used. This time the fish were infected either by intramuscular injection or by dipping them in a suspension of bacteria immediately after one of the pectoral fins was clipped. Unfortunately, again the infection of all available brook and brown trout with *B. salmonicida* obscured the results with those species. The findings were clear-cut only with rainbow trout (Table 2; Fig. 2). Bacteria associated with ulcer disease were recovered in pure culture from all rainbow trout examined that had been injected intramuscularly. In the several rainbow trout from this group that survived the acute stage of infection, the typical ulcers appeared. The development of these lesions followed the sequence described in the ulcer disease by Fish (1934) and Wolf (1939). Within several weeks

TABLE 1.—*Summary of results of first experiment on the inoculation of yearling trout with ulcer-disease bacteria*

[Each column gives the results from fish in a single trough. The trout were placed in the troughs on January 8 and those not in the control lots inoculated as indicated on January 9]

Item	Rainbow trout			Brook trout			Brown trout		
	Control	Intra-peritoneal	Sub-cutaneous	Control	Intra-peritoneal	Sub-cutaneous	Control	Intra-peritoneal	Sub-cutaneous
Initial number of fish	21	21	21	21	21	21	21	21	21
Mortalities									
January 9	..	..	..	..	1	1	..	..	..
do. 10	..	..	..	1	..	..	..	..	..
do. 11	..	..	..	..	..	1	..	..	..
do. 12	..	..	..	..	..	1	..	..	..
do. 13	..	7	..	..	14	8	..	1	1
do. 14	..	8	12	1	5	10	..	11	11
do. 15	..	5	6	1	1	..	..	6	5
Total mortalities	..	20	18	3	21	21	..	18	17
Percentage mortality	..	95	86	14	100	100	..	86	81
Bacteriological examination of dead trout									
Number examined	0	8	5	0	7	7	0	7	6
Ulcer disease bacteria isolated	..	8	4	..	0	1	..	..	1
B. salmonicida isolated	..	0	1	..	7	6	..	7	5

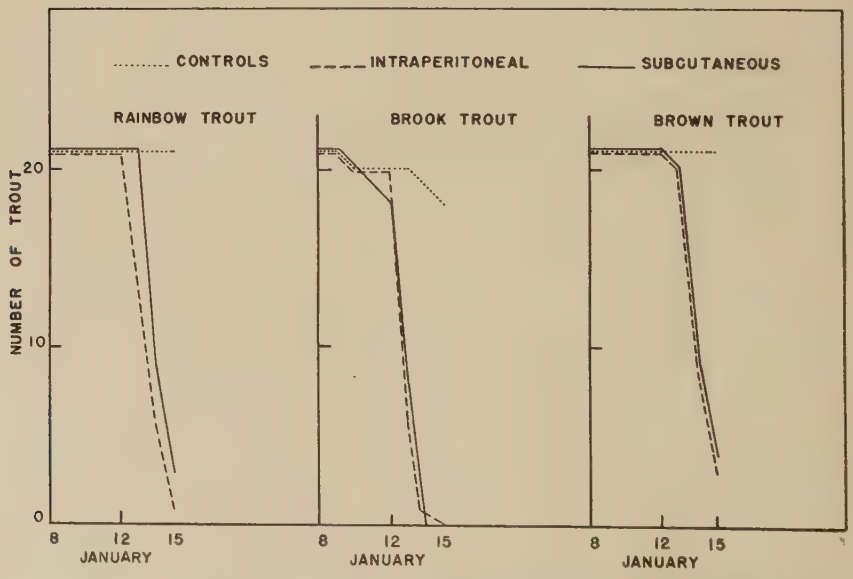

FIGURE 1.—Mortality of yearling trout inoculated on January 9 with living, virulent cultures of bacteria isolated from ulcer disease.

TABLE 2.—*Summary of results of the second experiment on the inoculation of yearling trout with ulcer-disease bacteria*

[Each column gives the results from fish in a single trough. The trout were placed in the troughs on March 2 and those not in the control lots inoculated on the same day]

Item	Rainbow trout			Brook trout			Brown trout		
	Control	Fin-clipped and dipped	Intra-muscular	Control	Fin-clipped and dipped	Intra-muscular	Control	Fin-clipped and dipped	Intra-muscular
Initial number of fish	10	10	10	10	10	10	10	10	10
Mortalities									
March 3	..	..	..	..	..	1	..	..	..
do. 4	..	..	..	..	..	..	..	..	..
do. 5	..	..	..	..	..	..	..	..	1
do. 6	..	..	..	1	..	1	..	..	2
do. 7	..	..	..	..	1	..	2	1	..
do. 8	..	..	..	..	..	..	2	..	..
do. 9	..	..	..	..	1	1	..	..	..
do. 10	..	..	1	1	2	1	..	2	..
do. 11	..	..	1	..	1	2	..	3	3
do. 12	..	..	..	..	2	1	1	..	..
do. 13	..	..	..	..	..	1	1	..	1
do. 14	..	..	..	1	..	..	..	..	..
do. 15	..	..	3	..	..	..	2	..	1
do. 16	..	..	1	2	..	..	..	..	..
do. 17	..	..	1	1	..	..	..	..	1
Total mortalities	..	..	7	6	7	8	8	6	9
Bacteriological examination of dead trout									
Number examined	..	..	7	5	6	7	8	6	9
Ulcer disease bacteria isolated	..	..	7	0	0	[1]6	1	0	[2]6
B. salmonicida isolated	..	..	0	4	6	1	7	6	3

[1] In 3 out of 6 trout, *B. salmonicida* also was present
[2] In 5 out of 6 trout, *B. salmonicida* also was present

these lesions were almost completely healed. In the brook trout and brown trout the ulcer-disease bacteria were recovered in pure culture, or with *B. salmonicida,* only from fish that had been inoculated intramuscularly. *B. salmonicida* was isolated regularly in pure culture from brook trout and brown trout which died in the control lots and also in the lots with clipped fins. From one of the brown trout of the control group, the ulcer disease bacteria were isolated in a mixed culture with *B. salmonicida.*

In the third experiment yearling brook trout were inoculated intramuscularly with bacteria isolated from ulcer disease. The control fish were divided in several batches, each of which was treated in a different way (Table 3). Again the brook trout used in this experiment were infected with *B. salmonicida* which was isolated from nearly all of the control fish which died. The trout injected with live bacteria isolated from ulcer disease all yielded the typical bacteria in pure culture from the local lesions which formed at the place of inoculation.

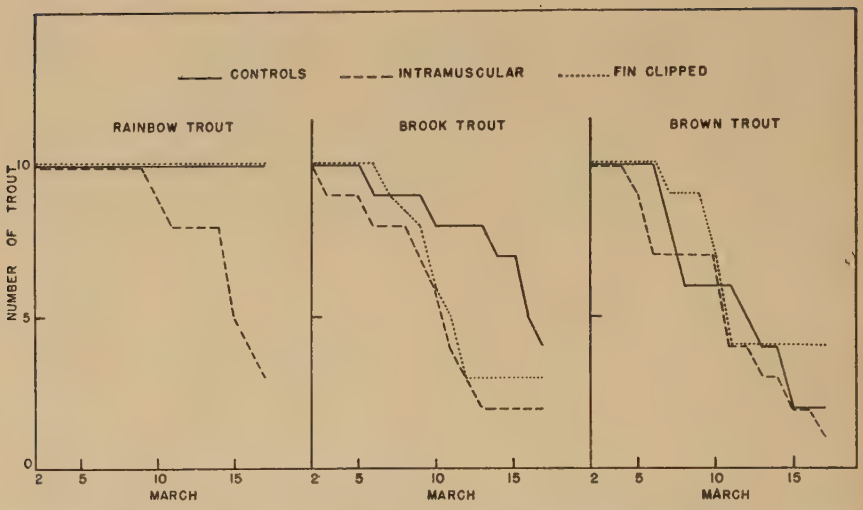

FIGURE 2.—Mortality of yearling trout inoculated on March 2 with living, virulent cultures of bacteria isolated from ulcer disease.

These three inoculation experiments indicated that the bacteria isolated from trout with ulcer disease, when introduced parenterally, were pathogenic to all the three species of trout tested. In rainbow trout, which were free from infection with *B. salmonicida,* the results were clear-cut. In brook trout and brown trout which already suffered from an infection with *B. salmonicida,* the results were obscured by furunculosis. Nevertheless, the bacteria which were used for inoculation were found to be pathogenic, and

TABLE 3.—*Summary of results of the third experiment on the inoculation of brook trout yearlings with ulcer-disease bacteria*

[Each column gives the results from fish in a single trough. The trout were placed in the troughs on March 18 and those not in the control lots were inoculated as indicated on March 19. Day-by-day mortalities are not given because the course of infection was about the same as in the first two experiments. Isolations were made from the local lesions or from the kidney if lesion was absent]

Item	Method of inoculation				
	Control	Control (saline, intramuscularly)	Control (pectoral fin clipped)	Live bacteria intramuscularly)	Control (killed bacteria and phenol, intramuscularly)
Initial number of fish	12	11	11	12	12
Total mortalities, March 19 to April 1	12	9	6	12	10
Bacteriological examination of dead trout					
Number examined	12	9	6	12	10
Ulcer disease bacteria isolated	0	1	0	11	0
B. salmonicida isolated	11	8	6	[1]2	9

[1] Small colonies and *B. salmonicida* in one trout

were reisolated frequently in pure culture from the lesions produced at the place of inoculation, or from the material removed from the kidney and dorsal vein.

ACNOWLEDGEMENT

The authors wish to express their thanks to Mr. E. W. Surber, Superintendent of the Station, for his wholehearted support of these investigations, and to Mr. B. H. Hazen, fish-culturist, for his genuine cooperation.

LITERATURE CITED

BREED, ROBERT S., E. G. D. MURRAY, and A. PARKER HITCHENS
1948. Bergey's manual of determinative bacteriology. Sixth ed., The Williams and Wilkins Company, 1,529 pp.

CALKINS, GARY N.
1899. Report upon the recent epidemic among brook trout (*Salvelinus fontinalis*) on Long Island. Fourth Ann. Rpt., N.Y. Comm. Fish Game and Forests, pp. 175–189.

FISH, FREDERICK F.
1934. Ulcer disease of trout. Trans. Am. Fish. Soc., Vol. 64, pp. 252–258.

REED, G. B., and G. C. TONER
1942. *Proteus hydrophilus* infections of pike, trout, and frogs. Canad. Jour. Res., Vol. 20, Sec. D, pp. 161–166.

SCHÄPERCLAUS, WILHELM
1941. Fischkrankheiten. (Second edition) Gustav Wenzel und Sohn, Braunschweig Germany. 296 S.

WOLF, LOUIS E.
1939. Observations on the ulcer disease of trout. Trans. Am. Fish. Soc., Vol. 68 (1938) pp. 136–151.
1941. Further observations on ulcer disease of trout. Trans. Am. Fish. Soc., Vol. 70 (1940) pp. 369–381.

SOCIETY OF AMERICAN BACTERIOLOGISTS
1948. Manual of methods for pure culture study of bacteria. (Revision of October, 1948) Society of American Bacteriologists, Geneva, New York. (Ten leaflets).

THREE YEARS OF LIBERALIZED FISHING AT LAKE ALMA, OHIO

JOHN Z. PELTON

Ohio Division of Conservation
Waverly, Ohio

ABSTRACT

Lake Alma, a 72.5-acre lake in southern Ohio, has been checked for fish production from 1937 through 1947. During 1945–1947 no length limits, bag limits, nor closed seasons were imposed. Test-netting and creel census before and since 1945–1947 indicate no measurable difference in fish populations or in angler's success due to liberalized fishing.

INTRODUCTION

Lake Alma is an artificial lake created in 1900 in Clinton Township, Vinton County, southern Ohio. The recreational uses of the lake were leased to the State of Ohio in 1931 and since then it has been under the administration of the Ohio Division of Conservation. The lake occupies 72.5 acres or 16 percent of the total drainage area of 499.2 acres. The one tributary stream of consequence is limited to winter, spring, and early-summer flow. Seventy-three percent of the drainage area is in forest, 25 percent is in pasture, and 2 percent is cultivated.

Lake Alma is impounded by an earth dam, approximately 1,500 feet long, built across an oxbow of Little Raccoon Creek. The lake, which lies 680 feet above sea level, is nearly circular and has an island in its center. At spillway crest the lake contains 701.9 acre feet of water with 20 percent of the area less than 4 feet deep, 26 percent varying between 4 and 10 feet, and 54 percent over 10 feet deep. It has 125 feet of shoreline per acre.

In spite of the low ratio of drainage area to water area, the level of the lake is nearly constant under normal conditions. The water is so clear that, except under unusual circumstances, a Secchi disc can be seen at from 8 to 10 feet the year around. From monthly observations, pH averaged 5.5 during 1945, 1946, and 1947. Dissolved oxygen ranged from 3.0 p.p.m. to 14.5 p.p.m. except in the deepest part of the lake.

Bottom organisms, primarily midge larve (*Chironomus*), are fairly abundant and number on an average 1,378 per square yard. Few other aquatic insects of importance are found in the lake except in the vegetation beds where nymphs of various dragonflies and damselflies occur.

Spatterdock (*Nymphaea advena*) is the predominant species of vegetation with occasional stands of white water lily (*Castalia odorata*). Cattails (*Typha*), bulrush (*Scirpus*), and water willow (*Dianthera americana*) are present along the shores.

Beginning in April 1945 a continual daily creel census has been made. This census has included number of fishermen, fishermen's home county and state, number of hours fished (including time of day), number and kinds of fish caught, length in inches, weight in ounces, boat or shore fishing (open water or vegetation), kinds of bait used (number of fish caught on kind of bait), and number and kinds of fish returned to water.

Standard commercial fyke nets were set seasonally and sometimes monthly to check on population and growth and to provide comparisons with the creel census.

Results of Creel Census

Fishing pressure (fishermen hours) was fairly constant over the years 1945–1947. Actual counts in 1946 and 1947 indicated 42 and 45 fishermen respectively per acre during the fishing season.

It is also apparent that late-summer and fall fishing is much better than spring and early-summer fishing, although June seems to be the best month for bass. Bluegills and largemouth black bass made up well over 90 percent of all fish caught. Large brown bullheads were numerous, but constituted only about 5 percent of the total catch of fish. Fish removal varied from 10 to 20 pounds per acre per year.

Because of its clearness, Lake Alma had long been believed to have better night than day fishing. However, daytime fishing (8 a.m. to 5 p.m.) was nearly twice as good as night fishing.

Worms were by far the most successful bait, accounting for nearly 60 percent of all fish caught.

Fish-Management Practices

During 1937–1938 various kinds of devices and shelters for fish were built in Lake Alma, according to designs said to be successful in other states. The following structures were installed: 163 rock shelters, 59 brush shelters, 42 slab troughs, 5 spawning ditches, 20 large logs, 9 slab platforms, and 2 raft shelters.

Stocking records which go back to 1932 show that nine species of fish have been planted (Table 1). Bluegills, brown bullheads, largemouth black bass, and bluntnose minnows were introduced in greatest numbers. No fish have been stocked since 1942 and no bluegills have been stocked since 1939. During the 1945–1947 period all length limits, bag limits, and closed seasons were removed.

Evaluation of Management Procedures

The Ohio Conservation Commission eliminated all legal lengths, bag limits, and closed seasons on Lake Alma fish beginning in 1945. Starting in April 1945 a creel census was taken daily through 1947. This census included actual interviews of over 80 percent of all fishermen. From 1937–1943 inclusive, occasional, random, creel-census surveys were made.

TABLE 1.—*Records of stocking of fish and other organisms in Lake Alma, Ohio*

Species	Number stocked in calendar year						
	1932–36	1937	1938	1939	1940	1941	1942
Green sunfish (*Lepomis cyanellus*)	.....	.....	75	.....	.....	...	...
Bluegills (*Lepomis macrochirus*)	125,279	.....	6	3,500	.....	...	...
Largemouth black bass (*Micropterus salmoides*)	8,289	.....	117	2,200	1,000	500	200
Brown bullhead (*Ameiurus nebulosus*)	17,052	78,069	12,821	4,661	.....	...	1,000
Channel catfish (*Ictalurus lacustris*)	1,600	.....	707	500	.....	...	...
White crappies (*Pomoxis annularis*)	2,100	.....	25	.....	.....	...	...
White sucker (*Catostomus commersonnii*)	83	.....	128	.....	.....	...	...
Gizzard shad (*Dorosoma cepedianum*)	2,400	.....	167	.....	4,805	1,650	...
Bluntnose minnow (*Hyborhynchus notatus*)	.....	124,846	268,299	286,000	208,867	...	...
Crayfish	34,700	10,000	13,660	3,651	15,875	...	...
Tadpoles	.....	.....	2,700	.....	4,000	...	...
Frogs	.....	.....	1,619	.....	.....	...	...
Total	156,803	212,915	300,324	300,512	234,547	2,150	1,200

The success of anglers in 1945, the first year of liberalized fishing, was at an all-time low and in 1947 had barely returned to the average for years prior to 1944 (Table 2). Fishing pressure was low in 1945, with 74 fisherman-hours per acre recorded. In 1946 and 1947 fishing pressure increased to 175 and 148 fisherman-hours respectively, per acre.

Bluegills made up 85 percent and largemouth black bass 7 percent of all fish caught by fishermen in 1947 which was a typical year. Large bullheads were numerous in Lake Alma but constituted only about 1 percent of the total anglers' catch (Table 3). The quantity of fish removed varied from 10 to 20 pounds per acre each year.

Test-net data from the years 1941, 1945, and 1946 do not indicate any decrease in the abundance of fish as a result of liberalized fishing (Table 4.) Although the catch per hour (0.54) in 1945, the first year of liberalized fishing, was less than in 1941 (0.74), the mean catches in 1946 and 1947 (3.80 and 1.00, respectively, were far above the 1941 level.

Bluegills captured in the test nets maintained an average length of over

TABLE 2.—*Number of fish caught per hour by anglers in Lake Alma*

[Observations were made in the months April–August, inclusive. No data for 1944]

Year	Fish caught per hour	Year	Fish caught per hour
1937	0.90	1942	0.73
1938	0.75	1943	0.77
1939	0.80	1945	0.43
1940	0.76	1946	0.52
1941	0.82	1947	0.83

TABLE 3.—*Creel-census record for Lake Alma in 1945–1947*

Item	Calendar year		
	1945	1946	1947
Total number of fishermen	2,250	3,631	4,125
Number of hours fished	5,834	12,797	13,465
Number of fish caught	2,788	5,799	10,797
Number of fish caught per hour	0.48	0.45	0.80
Pounds of fish removed per acre	9.95	19.38	13.19
Percentage of each species			
Largemouth black bass	38.19	13.84	6.80
White crappie	0.10	0.07	0.04
Bluegill	55.12	80.49	85.56
Yellow bullhead[1]	.....	0.41	0.75
Green sunfish	3.29	1.10	2.15
Longear sunfish[2]	.....	0.53	0.45
Pumpkinseed[3]	.....	0.53	1.20
Yellow perch[4]	1.54	0.53	0.75
Rock bass[5]	.....	.....	0.02
Brown bullhead	1.64	2.15	1.19
Black bullhead	.....	0.13	0.47
Channel catfish	.....	0.07	.....

[1] *Ameiurus natalis* [2] *Lepomis megalotis* [3] *Lepomis gibbosus*
[4] *Perca flavescens* [5] *Ambloplites rupestris*

7 inches during 1945–1946 but decreased to about 6½ inches in 1947. Largemouth black bass averaged a fraction over 10 inches in length during these years. Brown bullheads averaged more than 10 inches long in 1945, and over 11 inches in 1946–1947.

Growth-rate studies indicated that bluegills lived over 6 years in Lake Alma, and although the rate of growth appears to be nearly constant the age composition varied, apparently with some regularity.

The largemouth black bass was the only species of fish subject to a closed season (April 15–June 1) in southern Ohio. Beginning in 1945 the closed season was eliminated at Lake Alma. More largemouth black bass were removed in June by anglers than during the period which normally would have been a closed season (Table 5). There has been no indication of any difference in the fish population in Lake Alma due to the removal of the closed season.

Prior to the removal of all bag limits in 1945 at Lake Alma that lake had been subject to the State of Ohio's limit of 6 largemouth black bass and 20 bluegills per day. For the 3-year period 1945–1947, less than 1 percent of the fishermen took what would normally have been the limit of largemouth black bass and less than 3 percent took what would normally have been the limit of bluegills (Table 6).

All legal lengths also were removed in 1945. Largemouth black bass was the only species of fish in the lake which was affected by this action. The legal length for the state for largemouth black bass was 10 inches. In spite of the lack of legal length limits, less than 2 percent of all largemouth black bass caught that would have been below legal length under the regulation prescribed for the rest of the state, were kept by the anglers.

TABLE 4.—*Records of test-netting operations in Lake Alma, Ohio, in 1941 and 1945–1947*

[The numbers of hours of fishing in the several years were: 1941–2,223, 1945–1,106, 1946–581, 1947–2,378]

Species	1941			1945			1946			1947		
	Number of fish caught	Percentage of total catch	Number caught per hour	Number of fish caught	Percentage of total catch	Number caught per hour	Number of fish caught	Percentage of total catch	Number caught per hour	Number of fish caught	Percentage of total catch	Number caught per hour
Bluegill	578	63	0.54	121	20	0.10	1,647	71	2.70	1,773	78	0.80
Longear sunfish	2	0.50	....	...	....	....	...	....	....	...	....	....
Pumpkinseed	26	....	0.02	...	....	....	...	....	....	...	....	....
Green sunfish	3	0.50	....	...	....	....	...	....	....	25	1	0.00
Black crappie	21	2.00	0.01	...	....	....	3	....	....	...	....	....
White crappie	3	0.50	....	2	....	....	37	2	0.10	11	....	....
Largemouth bass	46	5	0.03	65	11	0.05	94	4	0.20	148	7	0.10
Rock bass	...	....	....	...	....	....	...	....	....	1	....	....
Black bullhead	2	0.50	....	...	....	....	1	....	....	17	....	....
Yellow bullhead	28	3	0.02	...	....	....	3	....	....	15	....	....
Brown bullhead	171	19	0.10	198	33	0.18	192	9	0.30	212	9	0.10
Yellow perch	3	0.50	....	4	1	....	40	2	0.10	4	....	....
White sucker	28	3.00	0.02	198	33	0.18	158	7	0.30	64	3	....
Golden shiner[1]	5	1.00	....	...	....	....	...	....	....	...	....	....
Grass pickerel[2]	3	0.50	....	...	....	....	...	....	....	...	....	....
Total or average	919	....	0.74	607	....	0.54	2,187	....	3.80	2,264	....	1.00

[1] *Notemionus crysoleucas* [2] *Esox vermiculatus*

TABLE 5.—*Numbers of largemouth black bass removed by anglers from Lake Alma, Ohio, during April, May and June 1945–1947*

[The legal closed season on black bass in southern Ohio is April 15–June 1]

Month	Calendar year		
	1945	1946	1947
April	27	40	9
May	149	281	47
June	246	232	97
Total	422	553	153

TABLE 6.—*Number and percentage of fishermen taking legal bag limits of largemouth black bass and bluegills during three years of liberalized fishing at Lake Alma, Ohio*

[Percentage based on ratio of fishermen who caught their legal limit to the total number of anglers contacted. In waters subject to bag limits the maximum legal numbers of fish per day were: largemouth black bass — 6; bluegills — 20]

Year	Anglers taking limit of largemouth black bass		Anglers taking limit of bluegills	
	Number	Percentage	Number	Percentage
1945	4	0.17	54	2.40
1946	25	0.68	40	1.10
1947	8	0.19	43	1.04

CONCLUSIONS AND RECOMMENDATIONS

Lake Alma is manageable (physically) both because of its small size and because of a gate and valve through which water can be removed from the lake.

Since 1937 nearly every phase of management in common use plus many others have been tried. Procedures included heavy stocking of forage fish, heavy stocking of game species, no stocking at all, provision of sanctuaries, construction of special rearing ponds alongshore for various purposes, planting and removing aquatic vegetation, the construction of cover and feeding devices for fish and of heavier devices to attract fish and fishermen, and liberalized fishing regulations (no bag limits, closed seasons, or legal lengths). Over this period of time no great change in fish populations or in the success of fishermen resulted from our efforts. It is apparent that natural conditions within the lake have superceded all man's efforts to productivity.

It is accordingly recommended that future management include continued liberalized fishing and continued curtailment of stocking.

THE QUANTITATIVE EFFECTS OF A DAM UPON THE BOTTOM FAUNA OF A SMALL CALIFORNIA STREAM[1]

JOHN CARMON BRIGGS

School of Biological Sciences
Stanford University, California

ABSTRACT

The effect of a dam upon the bottom-fauna production of Stevens Creek was tested for a 9-month period. The function of this dam being to catch flood waters and subsequently release them gradually, it has reduced the variations in water flow of the rainy season and has brought about a marked change in the physical appearance of the stream bed below the dam.

Production of bottom organisms, both in number and weight, was much greater in the area below the dam than above. A sharp, spring peak of production occurred on March 1 in both of the sampling areas. The period of minimum production coincided with the periods of greatest fluctuations in flow and lowest water temperatures. The greatest extremes of flow and temperature took place above the dam. The population above the dam fell to a much lower point during the period of minimum production than did the population below the dam.

Three types of aquatic insect larvae formed 81.3 percent of the total number of organisms taken. Caddicefly larvae contributed 45.1 percent, mayfly larvae 25.8 percent, and stonefly larvae 10.4 percent. The caddicefly larvae alone accounted for most of the increased faunal production below the dam. The mayfly larvae showed remarkable resistance to the floods and lower temperatures above the dam and were taken in much greater numbers in this area.

The numbers and weights of animals taken from the riffle areas greatly exceeded the numbers and weights from the pool areas. Pool organisms were somewhat protected from flooding but were exposed to the same temperature conditions that affected the riffle areas. Low winter temperatures did not result in a marked reduction of organisms in this habitat.

INTRODUCTION

Practically all quantitative studies of the bottom fauna of streams have been done in connection with fishery investigations. Most of this work has been accomplished for the purpose of determining the amount of food available for the various species of stream-dwelling trout.

The importance of bottom organisms in trout streams is now widely recognized. In Embody's (1927) stocking table recommending particular numbers of trout to be planted in streams of various types, the relative richness of the bottom fauna was included as an important factor. The

[1] This paper is based on materials prepared for a thesis submitted to the Graduate School, Leland Stanford Junior University in partial fulfillment of the requirements for the degree of Master of Arts.

significance of the bottom fauna as trout food has also been recognized by Davis (1938) who observed that stream-survey work, including the taking of bottom samples, is an important step preparatory to the inauguration of any fish-management program.

The most comprehensive studies concerning the relationship of trout and bottom fauna were made by Needham (1938) and Lord (1933). They found that practically all trout food in streams could be divided into two categories: drift food and bottom fauna. The bottom fauna was by far the more important. Needham observed that the eastern brook trout (*Salvelinus fontinalis*) showed less dependency upon bottom organisms than did any other species; yet 66.2 percent of the annual food intake of this trout originated in the bottom fauna. Other investigators working with different species of trout have reported a still greater dependency upon food from this source. In his studies of the rainbow trout (*Salmo gairdnerii*) of Waddell Creek in California, Shepherd [2] found that bottom fauna furnished over 93 percent of the food of this fish. Even organisms classed as drift food many times consist of bottom forms which have been torn loose from their habitat, or adult terrestrial insects which arose from aquatic larval stages.

Trout apparently display little selectivity in the choice of food. Needham (1938) has shown that in general they will eat the organisms that are most abundant on the stream bottoms. His data, from studies made in New York, show that the percentages of available foods correlate well with the percentages actually determined from the contents of fish stomachs.

More dams are being constructed each year on streams that support populations of trout, particularly in the western part of the country. These dams are being built principally for water storage, flood control, or hydroelectric power. Much has been written about the effects of these structures upon the migrations of anadromous fishes. There is little information, however, regarding the quantitative effects upon organisms constituting the bottom faunas, the principal food supply of both the migratory and resident trout populations. This paper is presented in an effort to help remedy this lack of information.

The Stream and Dam

Stevens Creek is a small permanent stream in the northwestern part of Santa Clara Valley, in central California. It rises in the Santa Cruz Mountains at an altitude of about 2,300 feet and has a mountain drainage area of 21 square miles. It has a total length of 19 miles and empties into San Francisco Bay near the town of Mountain View.

In its upper course Stevens Creek cuts through various rock formations, the majority of them sedimentary. As it leaves the highest mountains it flows about 5 miles through an area of alluvial deposits made up of

[2] Shephard, D. The Trichoptera of Waddell Creek and their relation to the food of the rainbow trout, *Salmo iridens*. 319 pp., 1928. [Typewritten thesis; Stanford University]

clay, silt, sand, gravel, and a number of large rocks brought down from the higher mountains. It is in this area that the dam and reservoir are located. Below this region the stream continues through older alluvial deposits until it reaches the bay.

According to Clark (1924), the average annual precipitation for this part of California is 16.58 inches. Less than 1 percent of the rain falls during the driest three months, whereas 56 percent is concentrated during the three months of greatest precipitation and 82 percent falls during the wettest five months.

The stream bed is divided about equally into riffle areas where the water is swiftly flowing and shallow and pool areas where the stream is wider and deeper, and flows slowly. The only fish found in the creek was the rainbow trout.

Stevens Creek Dam, located about 9 miles upstream from the mouth, is 120 feet high and 1,000 feet long. The reservoir covers an area of 95 acres and has a total storage capacity of 4,000 acre-feet. The purpose of the dam and the reservoir created by it is to trap the flood waters which normally run to waste in San Francisco Bay and subsequently release them gradually for percolation into the underground strata.

It should be noted that the rainfall during the winter season of 1946–1947 was far below normal. Consequently the amount of water stored was unusually small, reaching a maximum of only 885 acre-feet, or less than one quarter of the full capacity. On October 13, 1946, at the beginning of the study period, approximately 1,000 acre-feet of water was in storage. This residue of the flood waters stored during the winter of 1945–1946 served, with replenishment from November and December rains, to maintain a relatively constant flow of more than 7 cubic feet per second below the dam until January 1. The study was concluded on June 21, 1947, and within a week thereafter the reservoir was completely drained leaving the stream below the dam subject to minimal flow during the summer.

Problem and Program

The problem was to determine the quantitative effects of Stevens Creek Dam upon the bottom fauna of the stream. The stretches of stream which now lie immediately above and below the reservoir were quite similar before the dam was built. The same type of substrate, early alluvial deposits, was present and the stream gradient and flow were similar in both areas.

The influence of the dam in modifying the highly fluctuating water flow of the rainy season has resulted in a marked change in the stream-bed area below the dam. The stream bed itself, although it lies in the same type of geological structure as above the reservoir, presents an altered appearance. A large amount of finely divided material surrounds the stones of the riffle areas while the greater parts of the pool areas contain mud deposited on fine gravel. Alongside the stream the soil banks covered with vegetation and litter extend to the edge of the water (Fig. 1).

FIGURE 1.—View upstream over sampling area below the dam.

FIGURE 2.—View upstream over sampling area above the dam. Picture taken on same day as Figure 1.

Above the dam the large stones in the riffles are clean-swept, while the pools are composed of coarse, clean gravel and stones. In times of normal flow the water is found in the center of a wide bed of large boulders. On the banks, evidences of winter floods remain in the form of water-cut soil, exposed tree roots, and broken logs and branches, (Fig. 2).

Two general collecting areas were established. The one below the reservoir was located about one-half mile below the dam itself, near a stream-gauging station of the U. S. Geological Survey. The area above the reservoir was located near a road bridge about 2 miles above the high-water level of the lake. The station above the reservoir had to be located 2 miles upstream in order to avoid the influence of the public picnic grounds in the lower reaches.

The collecting was begun on October 13, 1946, and was continued every 2 weeks thereafter through June 21, 1947. All collections were made in the early afternoon. The water temperature was recorded and stream-flow calculated at the time the various collections were made. Since the pool and riffle areas of the stream were approximately evenly divided it was deemed advisable to take the same number of samples from each habitat. Accordingly, each complete collection consisted of 12 bottom samples, 6 from the station above the reservoir and 6 from below. Of the 6 samples collected from each station, 3 were taken from pools and 3 from riffles. Since 19 complete collections were made over a 9-month period, the total samples analyzed numbered 228.

All of the samples were taken with a standard stream bottom sampler. This instrument consists of two brass frames, each 1 foot square, hinged together; one frame is provided with a net and is held vertically while the other merely overlies the area to be sampled. A complete description of the sampler and of the method of its use is given by Davis (1938). In Stevens Creek it was possible to use the sampler in the pool areas as well as in the riffles since the majority of the pools were relatively narrow and shallow with a good current.

During the removal of the organisms from the substrate the sampler was applied closely to the stream bottom and held in place. All of the larger stones were washed carefully and the animals thus liberated were carried into the net by the force of the current. The finer material was then sifted and much of it was washed into the net along with additional organic material. The sampler was then removed from the stream and the contents of the net spread over the bottom of a large, white, enamel pan. The bottom organisms were immediately separted from the inorganic material and placed, after discarding the indigestible cases of the caddicefly larvae, in labeled vials containing 95-percent ethyl alcohol. Each sample was weighed on a sensitive balance scale, and the different types of organisms were separated and counted.

At the time each collection was made the volume of water flow was calculated in cubic feet per second, by means of the standard float method over a 100-foot section. These stream flows were later corrected, where

necessary, upon the receipt of more accurate data from the U. S. Geological Survey and the Santa Clara Valley Water Conservation District.

The temperatures (C.°) were determined with a standard laboratory thermometer immersed in the center of the stream.

Productivity Above and Below the Dam

Comparisons of the samples from above and below the dam demonstrated that the latter region was by far the more productive. The total weight of the 114 samples collected above the dam was 40.55 grams, and the total weight from below the dam was 86.52 grams. The average weight of samples taken above the dam was 0.35 gram, while that taken below the dam was 0.75 gram. The weights of organisms collected at each station during the collecting periods are recorded in Table 1 and graphically in Figure 3. Each value represents the total weight of the six samples collected in the indicated area. Only on October 13, 1946, and on April 13, 1947, did the weight of organisms taken above the dam exceed the weight of those taken below. On both dates the difference between the two stations was very slight.

The difference between the numbers of organisms in the samples taken above and below the dam were almost equally as striking. Of the total

Table 1.—*Rate of flow, water temperature, and weight and number of organisms for six square feet of stream bottom in Stevens Creek, California, on different collecting dates*

[Each weight or number of organisms is the total for six 1-square-foot samples]

Date of collection (1946–1947)	Stream above dam				Stream below dam			
	Flow (cubic feet per second)	Water temperature (C.°)	Weight of organisms (grams)	Number of organisms	Flow (cubic feet per second)	Water temperature (C.°)	Weight of organisms (grams)	Number of organisms
October 13	0.2	13.0	3.46	99	9.0	15.2	2.43	95
do. 27	0.5	9.9	2.35	74	8.4	14.0	3.23	144
November 10	0.5	6.9	1.41	73	8.0	12.0	2.20	106
do. 24	3.0	8.0	0.70	28	7.6	11.0	2.36	96
December 8	2.4	7.0	0.81	29	7.3	8.9	3.02	105
do. 22	3.5	8.8	0.97	60	7.3	10.8	4.23	143
January 6	3.0	4.0	0.98	61	7.0	7.3	3.85	139
do. 20	3.2	3.0	0.67	60	2.2	6.0	2.40	102
February 3	5.9	5.8	0.69	40	2.2	10.0	4.36	126
do. 17	8.2	10.0	0.42	26	4.8	11.2	4.07	103
March 1	8.0	10.2	5.23	89	4.8	11.2	9.48	235
do. 15	6.8	10.9	3.25	85	5.3	11.2	6.32	192
do. 29	6.0	12.1	3.98	87	6.1	11.2	6.73	119
April 12	4.9	11.7	4.02	110	7.0	14.0	3.28	123
do. 26	4.1	13.0	2.14	93	7.0	14.0	4.06	81
May 10	3.0	13.6	1.22	41	3.0	15.0	7.37	162
do. 24	2.1	14.2	2.32	87	3.0	15.8	8.61	164
June 7	2.0	15.5	3.43	109	3.0	16.2	5.55	108
do. 21	1.5	15.8	2.50	73	13.0	16.2	2.97	55

number (3,723) from all samples, 35.6 percent came from above the dam, whereas 64.4 percent came from below the dam. Samples taken above the dam had an average of 11.6 organisms while 21.0 organisms were present in the average sample taken below the dam. The numbers of animals at each station during each collecting period are represented on the graph of Figure 4 (see also Table 1). Again, each value represents the total for

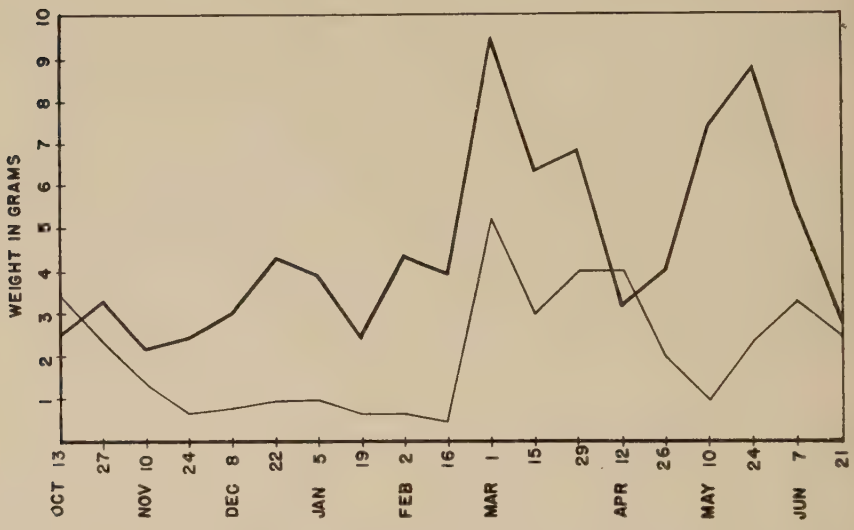

FIGURE 3.—Total weights of organisms from 6 square feet of stream bottom above (light line) and below (heavy line) Stevens Creek Dam.

six samples collected in the indicated area. On only three dates did the numbers of organisms in samples taken above the dam exceed those collected at the lower station. These dates were October 13, 1946, April 26, 1947, and June 21, 1947. On each of these dates the difference in the number of organisms taken at the two localities was very small.

EFFECTS OF TEMPERATURE AND FLOW

It can be noted from Table 1 and Figures 3 and 4, that beginning in February a sharp increase in numbers and weights of organisms took place both above and below the dam. A similar phenomenon was noticed by Needham (1938) at Waddell Creek, a small coastal stream about 40 miles from Stevens Creek. His findings indicated that two peaks of seasonal abundance could be expected to occur—a large peak in the spring and a small one in the fall. A similar observation was reported from the eastern part of the country when Surber (1936) reported a large peak of abundance on Big Spring Creek, Virginia, in early June.

In Figure 5 the weights of the samples taken above the dam have been plotted together with the data on temperature and flow (see also Table 1). The flood peaks represented on the graph are approximations estimated from high-water marks. The only actual measurements of flow were made at the time of each collection. The first large flood took place on December 4, 1946, when the flow reached a maximum of about 50 cubic feet per

FIGURE 4.—Total numbers of organisms from 6 square feet of stream bottom above (light line) and below (heavy line) Stevens Creek Dam.

second. The second flood (January 27, 1947) attained a maximum of about 30 cubic feet per second. It can be seen that the periods of highly fluctuating water flow and lowest temperature correspond closely with the period during which the production of the bottom fauna was lowest.

In a like manner Figure 6 illustrates the variations which occurred in the weights of organisms below the dam plotted together with the data on temperature and flow which affected this area. Below the dam the fluctuation in flow was comparatively slight and the temperature of the water dropped to a minimum of only 6° C. as compared with 3° C. in the upper area. In this lower portion of the stream the weight dropped to a winter minimum of only 2.20 grams as compared with 0.42 gram above the reservoir. With the cessation of rainfall and the increase in water temperature, the area below the dam reached a peak spring production of 9.48 grams on March 1. The area above the dam reached the spring peak on the same date but it amounted to only 5.23 grams.

In general, it is known that a highly fluctuating water flow can be extremely destructive to the bottom fauna. Moffett (1936) reported that some streams which he examined in Utah were swept almost completely bare of all aquatic life by floods. The destructive pounding and grinding force of the shifting substrate can quickly reduce most of the bottom fauna to unrecognizable bits of detritus. In Stevens Creek fairly large amounts of broken organic matter were found in the bottom sampler above the dam immediately after periods of flood.

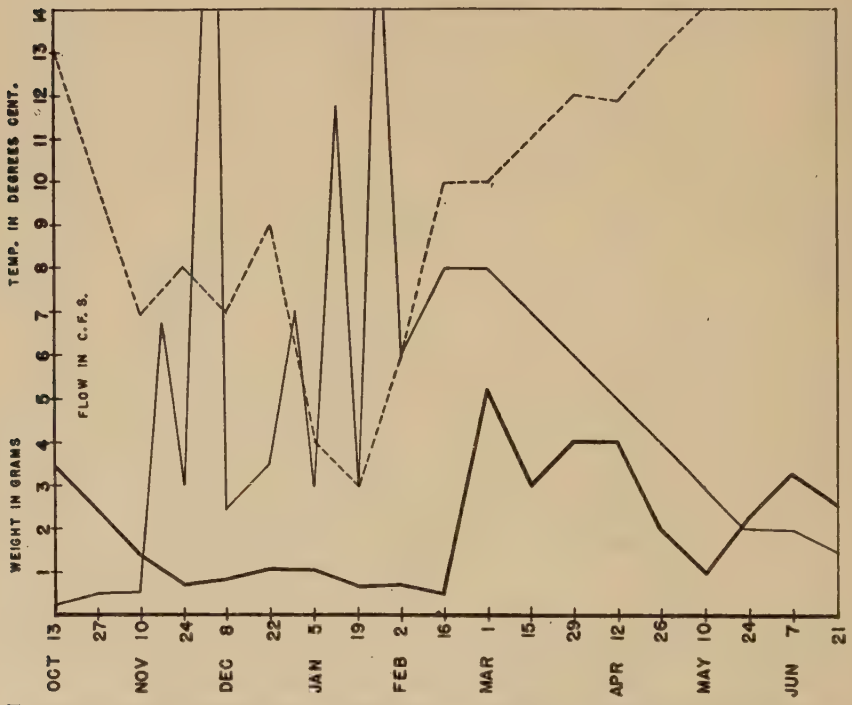
TEMP. IN DEGREES CENT.
FLOW IN C.F.S.
WEIGHT IN GRAMS
1 2 3 4 5 6 7 8 9 10 11 12 13 14
OCT 13 27
NOV 10 24
DEC 8 22
JAN 5 19
FEB 2 16
MAR 1 15 29
APR 12 26
MAY 10 24
JUN 7 21

FIGURE 5.—Flow measurements (light line), temperature (dotted line), and sample weights (heavy line) taken above Stevens Creek Dam.

Apparently periods of reduced flow present a much less serious problem to the bottom organisms than do periods of flood. From Table 1 and Figure 5 it may be seen that during the sampling periods of October 13 and 27, May 24, June 7, and June 21 a relatively slight flow of water (2 cubic feet per second or less) was sufficient to maintain a fairly rich bottom fauna. A higher flow is probably necessary, however, for maximum production since the spring peak occurred at a flow of 8 cubic feet per second. Probably the only destructive effect of low water flow is the

decrease in habitable areas and perhaps the destruction of some forms by stranding and desiccation.

It seems reasonable to conclude that unstable water flows above the dam, particularly the floods, were an important factor in keeping the winter population of bottom organisms at a low level in that area. The low water temperatures characteristic of the same time of year were probably a contributing factor.

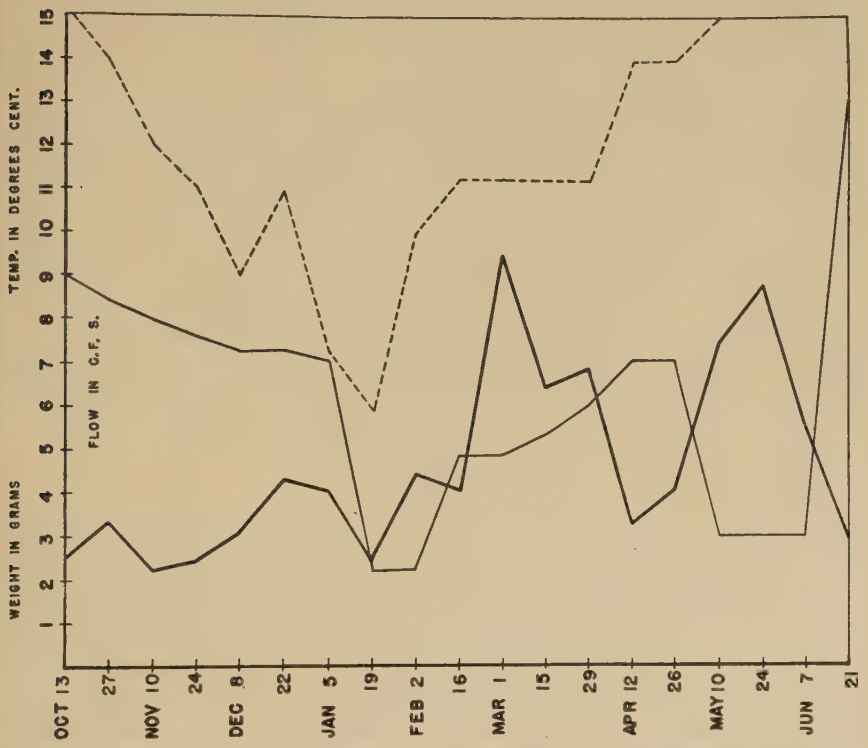

FIGURE 6.—Flow measurements (light line), temperatures (dotted line), and sample weights (heavy line) taken below Stevens Creek Dam.

DOMINANT FORMS AND THEIR DISTRIBUTION

Three types of aquatic insect larvae formed 81.3 percent or 3,028 individuals out of the total 3,723 organisms taken. The 1,676 caddicefly larvae constituted 45.1 percent of the total; 87.9 percent of these animals were found below the dam and 12.1 percent above. Practically all of the difference between production above and below the dam can be attributed to the caddicefly larvae. It is quite probable that these animals are much more

sensitive to the inhibiting factors of low temperature and high water flows than are the other common bottom forms.

The mayfly larvae contributed 963 individuals or 25.8 percent of the total of 3,723; 24.8 percent of these animals were found below the dam and 75.2 percent above.

The third most abundant organisms were the stonefly larvae. The 389 specimens formed 10.4 percent of all animals taken; 41.6 percent of the stoneflies were collected below the dam and 58.4 percent above. The remaining 18.7 percent of the total collection was composed chiefly of aquatic earthworms and the larvae of the Diptera, Coleoptera, and Odonata. Molluscs and crustaceans were few.

It was noticed during the collecting periods that the mayfly and stonefly larvae seemed to prefer a similar habitat, and were concentrated principally in riffle areas under rubble and larger rocks. This type of habitat is present both above and below the dam. However, the rubble and other rocks in the riffle areas below the dam were imbedded in large amounts of coarse sand and silt. Evidently the presence of this material prevented the mayfly and stonefly larvae from utilizing the under-rock habitats of this area. As a result, the populations of both of these types of larvae, particularly the mayflies, were somewhat larger above the dam. The mayfly larvae demonstrated a remarkable resistance to the normally inhibiting action of floods and low temperatures. They were produced in markedly greater numbers above the dam and were able to maintain their population at a high and even increasing level during the winter months when the abundance of other forms was much reduced.

Comparison of Productivity of Riffles and Pools

A sharp contrast was found between the numbers and weights of animals taken from the riffle areas and from the pools. Of the grand total weight of 127.07 grams, 106.54 grams occurred in the riffle areas while 20.53 grams were found in the pools. The average riffle sample weighed 0.93 gram and the average pool sample 0.18 gram. Of the grand total of 3,723 organisms, 76.2 percent were collected in the riffles and 23.8 percent were from pools. The average riffle sample contained 24.8 animals while the average pool sample had but 7.7.

Most of the difference between production above and below the dam and the greater part of the variation from date to date at a single station can be traced to fluctuations in total numbers and total weights in riffle areas. This situation is not surprising in view of the fact that approximately 80 percent of the total production originated in the riffle areas.

In contrast, production in pools both above and below the dam, although fairly low, was more or less constant throughout the period of study in both areas. No appreciable effect of either flow or temperature could be detected. It appears that limited flooding conditions are not greatly harmful to the pool-dwelling organisms, probably because the floods tend to pass over the top of the comparatively deep waters in the pools, leaving them

relatively undisturbed while at the same time creating the greatest destruction in the riffle areas.

The stability of the populations in the pool areas as compared to the wide fluctuations characteristic of the riffle areas indicates that low temperature must be relegated to secondary importance as an effective inhibiting factor, since both pools and riffles are characterized by the same temperatures. The one evident variable that might account for the differences in production between pools and riffles and for fluctuations in production in the latter habitat at different times is the rate of water flow. For two reasons, however, the temperature cannot be entirely discarded as an effective factor. First, comparatively few animals were taken from the pools compared to the riffle habitats, and second, the population curve of Figure 6 depicting the total production of both pool and riffle areas below the dam where the flow was comparatively stable appears to be more closely correlated with temperature than with flow.

Conclusion

This study has shown conclusively that the percolation dam on Stevens Creek has had a beneficial effect in increasing the production of stream-bottom fauna, particularly of caddicefly larvae. It indicates that the construction of dams that stabilize the water flow may be beneficial to the fish population resident in streams subjected to intermittent floods.

Literature Cited

Clark, William O.
1924. Ground water in Santa Clara Valley, California. U. S. Geol. Surv., Water-Supply Pap. No. 519, 181 pp.

Davis, H. S.
1938. Instructions for conducting lake and stream surveys. U. S. Bur. Fish., Fish. Circ. No. 26, 55 pp.

Embody, G. C.
1927. An outline of stream study and the development of a stocking policy. Contrib. Aquicult. Lab., Cornell Univ., 21 pp.

Lord, Russell F.
1933. Type of food taken throughout the year in a single Vermont stream with special reference to winter feeding. Trans. Am. Fish. Soc., Vol. 63, pp. 182–197.

Moffett, James W.
1936. A quantitative study of the bottom fauna in some Utah streams variously affected by erosion. Bull. Univ. Utah, Vol. 26, No. 9, (Biol. Ser., Vol. 3, No. 3), 32 pp.

Needham, Paul R.
1938. Trout streams. Comstock Publishing Co. Inc. Ithaca, N. Y., x + 233 pp.

Surber, Eugene W.
1937. Rainbow trout and bottom fauna production in one mile of stream. Trans. Am. Fish. Soc., Vol. 66 (1936), pp. 193–202.

CHANGES IN GROWTH RATES OF FISHES FOLLOWING REDUCTION IN POPULATION DENSITIES BY WINTERKILL [1]

WILLIAM C. BECKMAN

Michigan Department of Conservation
Ann Arbor, Michigan

ABSTRACT

Studies were made on four lakes in southern Michigan to determine the effect of the reduction in numbers of fish by winterkill upon the rate of growth of fishes. Earlier investigations on another body of water had demonstrated that a severe reduction in population density had a marked effect on the rate of growth of the survivors. At the time of the winterkill in 1945 scale samples and counts of dead fish were obtained. Samples have been collected each year since the kill. An increase in the rate of growth too great to be accounted for by annual variations followed the winterkill in all but one species from one lake. The increase in growth rate was not maintained, however, for longer than a year in most species. Further studies are suggested to determine possible methods of management which would increase and maintain the greater rate of growth.

INTRODUCTION

One of the methods that has been suggested for the improvement of growth rates of stunted fishes is the destruction of part of the population by chemical treatment. Beckman (1941, 1943) found an increased growth of rock bass (*Ambloplites rupestris*) too great to be explained by annual variation in growth following the removal of all fish in approximately one-half of Booth (Standard) Lake, Charlevoix and Otsego counties, Michigan. To check further on the value of this method and the extent to which the population must be reduced, several lakes subject to winterkill are being investigated.

THE LAKES AND THE EXTENT OF WINTERKILL

Batteese and Goose Lakes in Jackson County, Duck Lake in Montcalm County, and Green Lake [2] in Washtenaw County, Michigan, are subject to winterkill at relatively frequent intervals. Severe kills occur occasionally with lighter kills interspersed. Prior to the winter of 1944–1945, when

[1] Contribution from the Michigan Institute for Fisheries Research.

[2] Institute field parties visited many lakes other than the four treated in this study and made counts of dead fish. Some lakes originally included have been omitted for various reasons (inadequate sample counts, inadequate scale samples, . . .). Further collections are to be made from some of these lakes; if the additional material proves adequate, it may be incorporated into the study.

a heavy mortality occurred, the last severe mortality was in the winter of 1935–1936.

All of the lakes are shallow. Maximum depths are as follows: Batteese Lake, 15 feet; Goose Lake, 10 feet; Duck Lake, 9 feet; and Green Lake, 13 feet. Rooted vegetation is abundant over most of the bottoms of these lakes.

In early March 1945 when the ice cover melted, several members of the Institute staff visited the lakes, made counts of dead fish on measured sections of the shoreline, and took scale samples. At Batteese Lake it was estimated that 179,640 fish were killed (Table 1). No attempts were made

TABLE 1.—*Location, area and depth of the lakes and numbers of fish destroyed by one winterkill*

Item	Lake			
	Batteese	Goose	Duck	Green
Area (acres)	100	427	306	78.5
Maximum depth (feet)	15	10	9	13
Total, all species	179,640	81,838	[1]50,000	65,509
Fish per acre (all species)	1,796	193	163	835
Game fish	177,640	70,958	45,000	59,462
Bluegills	165,000	41,922	18,000	16,852
Largemouth black bass	2,400	13,922	4,500	1,512
Yellow perch	440	6,834	13,500	6,698
Black crappie	500	...	4,500	5,456
Pumpkinseed	2,600	7,378	...	23,452
Other species	8,700	11,782	4,500	11,539
Game fish per acre	1,776	167	147	758
Legal-sized game fish	41,712	24,499	33,750	17,263
Legal-sized game fish per acre	417	58	110	220

[1] Rough estimate; no counts made on sample areas

at any lake to count all of the small minnows or other small forage fishes. Counts were made, however, of the larger golden shiners (*Notemigonus c. crysoleucas*), chubsuckers (*Erimyzon sucetta kennerlii*), white suckers (*Catostomus c. commersonnii*), and other large rough fishes. Legal-sized game fish made up 23.5 percent of the kill, with the bluegill (*Lepomis m. macrochirus*) the dominant species. The ratio of bluegills to largemouth black bass (*Micropterus salmoides*) was 68:1. Since observations made by Dr. G. P. Cooper of the Institute on lakes subject to winterkill suggest that bluegills and largemouth bass are susceptible to winterkill in the same degree, the above ratio is believed to be fairly reliable.

In Goose Lake an estimation based upon sample counts gave a total of 81,838 fish destroyed in the 1944–1945 winterkill. Of this total 24,499 (34.5 percent) were of legal length. The ratio of bluegills to largemouth bass was 3:1.

No counts were made of dead fish along measured sections of shoreline in Duck Lake. A total of 50,000 fish was estimated to have been killed, but this figure may be considerably in error. The high percentage of legal-length fishes suggests that the estimate may be low. A population

in which 75 percent of the fish are legal-sized cannot be considered normal. The lack of actual counts also throws in doubt the accuracy of the 4:1 ratio of bluegills to largemouth bass although that value is not unusual.

In Green Lake where counts led to an estimate of 65,509 fish killed, legal-sized individuals made up 29 percent of the total. The ratio of bluegills to largemouth black bass was 11:1.

In Batteese Lake the bluegills were stunted, whereas in the other three lakes they were growing at a rate about equal to the average established for Michigan waters by Beckman (1949).

A slight winterkill occurred in Goose Lake in the winter of 1946–1947 and in Duck Lake in the winter of 1947–1948. The other waters have had no unusual mortality since 1944–1945.

Fluctuations in the Rate of Growth

Scale samples were taken from the dead fish at the time of the winterkill. Subsequently fish were taken by netting and hook-and-line fishing in the spring and summer of 1946, 1947, and 1948 (Table 2). Limited winterkills added specimens from two lakes. Standard techniques were followed in the preparation and study of the scale materials.

In the absence of any data on the body-scale relationships for the species involved, the growth increments for each calendar year of life were derived from direct-proportion calculations. Lee's phenomenon was so slight that it

Table 2.—*Number of specimens and dates of collection of materials for study of changes in growth rates following winterkill*

Species	Lake	Date of collection	Number of specimens
Bluegill	Batteese	March 1945	63
		July 1946	81
		June 1947	55
Bluegill	Goose	March 1945	68
		June 1946	12
		April 1947	160
		June 1947	7
Largemouth black bass	Goose	March 1945	62
		June 1946	4
		April 1947	60
		June 1947	2
Perch	Duck	March 1945	24
		July 1947	15
		April 1948	23
Perch	Green	August 1944	7
		March 1945	26
		June 1946	89
		May 1947	93
		July 1948	53
Pumpkinseed	Green	August 1944	10
		March 1945	23
		June 1946	55
		May 1947	9
		July 1948	21

was not considered sufficiently great to influence the averages significantly.

The method employed for the estimation of fluctuations in growth rate is illustrated by Tables 3, 4, 5, and 6, for the preparation of which the data on the Batteese Lake bluegill were selected. First, growth increments calculated for each age group for each year of life were compiled (Table 3). Second, to achieve a condensation of the data in which the increments were

TABLE 3.—*Growth increments by calendar years for the bluegill from Batteese Lake, during each year of life, before and after reduction in numbers by winterkill*

[Number of specimens in parentheses]

Year of life	Age-group	Calculated growth (millimeters) in total length for calendar year								
		Before winterkill							After winterkill	
		1938	1939	1940	1941	1942	1943	1944	1945	1946
	I	.....	.....	.....	.....	.....	.....	.....	38 (7)	.....
	II	.....	.....	.....	.....	.....	29 (8)	.....	39 (4)	.....
	III	.....	.....	.....	.....	31 (7)	28 (4)	26 (3)	.....	.....
1	IV	.....	.....	.....	31(16)	29(32)	25(26)	.....	.....	.....
	V	.....	.....	26(11)	29(26)	28(21)	.....	.....	.....	.....
	VI	.....	33 (9)	24(11)	25 (4)	.....	.....	.....	.....	.....
	VII	35 (9)	.....	.....	.....	.....	.....	.....	.....	.....
	II	.....	.....	.....	.....	.....	.....	39 (8)	.....	41 (4)
	III	.....	.....	.....	.....	.....	39 (7)	46 (4)	48 (3)	.....
2	IV	.....	.....	.....	.....	33(16)	37(32)	38(26)	.....	.....
	V	.....	.....	.....	38(11)	32(26)	36(21)	.....	.....	.....
	VI	.....	.....	38 (9)	36(11)	28 (4)	.....	.....	.....	.....
	VII	.....	42 (9)	.....	.....	.....	.....	.....	.....	.....
	III	.....	.....	.....	.....	.....	.....	38 (7)	53 (4)	35 (3)
	IV	.....	.....	.....	.....	.....	39(16)	33(32)	47(26)	.....
3	V	.....	.....	.....	.....	29(11)	34(26)	33(21)	.....	.....
	VI	.....	.....	.....	35 (9)	28(11)	25 (4)	.....	.....	.....
	VII	.....	.....	32 (9)	.....	.....	.....	.....	.....	.....
	IV	.....	.....	.....	.....	.....	.....	29(16)	46(32)	28(26)
4	V	.....	.....	.....	.....	.....	35(11)	29(26)	39(21)	.....
	VI	.....	.....	.....	.....	26 (9)	31(11)	29 (4)	.....	.....
	VII	.....	.....	.....	24 (9)	.....	.....	.....	.....	.....
	V	.....	.....	.....	.....	.....	.....	27(11)	34(26)	22(21)
5	VI	.....	.....	.....	.....	.....	26 (9)	24(11)	29 (4)	.....
	VII	.....	.....	.....	.....	17 (9)	.....	.....	.....	.....
6	VI	.....	.....	.....	.....	.....	.....	18 (9)	27(11)	19 (4)
	VII	.....	.....	.....	.....	.....	15 (9)	.....	.....	.....
7	VII	.....	.....	.....	.....	.....	.....	10 (9)	.....	.....

TABLE 4.—*Calculated annual increments (weighted average) of growth in length of various year classes of the bluegill from Batteese Lake*

[Number of specimens in parentheses]

Year of life	Increment (millimeters) of growth in calendar year								
	1938	1939	1940	1941	1942	1943	1944	1945	1946
1	35 (9)	33 (9)	25(22)	29(46)	29(60)	26(38)	26 (3)	38(11)	.....
2	.....	42 (9)	38 (9)	37(22)	32(46)	37(60)	39(38)	48 (3)	41 (4)
3	.....	.....	32 (9)	35 (9)	29(22)	35(46)	34(60)	48(30)	35 (3)
4	.....	.....	.....	24 (9)	26 (9)	33(22)	29(46)	43(53)	28(26)
5	.....	.....	.....	.....	17 (9)	26 (9)	26(22)	33(30)	22(21)
6	.....	.....	.....	.....	.....	15 (9)	18 (9)	27(11)	17 (4)

based on greater numbers of fish, the weighted average of the increments for each year of life were combined by calendar year as shown in Table 4. Third, the data for estimation of annual fluctuations in growth were set up in Table 5 in which are listed the sums of the increments from Table 4 for the same years of life but in successive calendar years. As an illustration, the sum of the increments for the first three years of life in 1940 ($25 + 38 + 32 = 95$) can be compared directly with the growth in corresponding years in 1941 ($29 + 37 + 35 = 101$).

TABLE 5.—*Tabulation of data used in the determination of the annual fluctuations in growth of the bluegill from Batteese Lake*

Years compared	Growth in earlier year (millimeters)	Growth in later year (millimeters)	Mean	Change in growth	Percentage change in growth
1938 and 1939	35	33	34	− 2	− 5.9
1939 and 1940	75	63	69	−12	−17.4
1940 and 1941	95	101	98	+ 6	+ 6.1
1941 and 1942	125	116	120.5	− 9	− 7.5
1942 and 1943	133	157	145	+22	+15.2
1943 and 1944	172	172	172	0	0.0
1944 and 1945	172	238	205	+66	+32.2
1945 and 1946	199	145	172	−54	−31.4

The changes between the successive calendar years were then reduced to a percentage basis by the procedure indicated in the righthand columns of Table 5. Finally, the percentages of Table 5 were added successively to give the relative positions of the several calendar years and then adjusted to a mean of 0.0 for the 7-year period (1938–1944) preceding the winterkill. The values after adjustment (top line of body of Table 6—see also Fig. 1) are the estimates of the annual percentage deviation of growth from the 1938–1944 mean.[3]

The fluctuations for other species and lakes recorded in Table 6 and Figure 1 were obtained by the same procedure. The data for the year 1938 for the bluegill from Batteese Lake were not included in the Figure 1 in order to reduce the size of the graph, since that year was represented only by the bluegill of Batteese Lake.

The growth of the bluegill in Batteese Lake prior to the winterkill, despite a certain amount of variation, was so slow in comparison with the average established for the state that they could be termed stunted. Growth improved decidedly in 1945 (35.6 percent above the 1938–1944 mean) but the fish did not attain the state average, and in 1946 growth declined almost to the average of the period before the kill.

Three of the five remaining curves in Figure 1 followed trends similar to that exhibited by the Batteese Lake bluegill—that is, the growth of the fish increased sharply immediately following the winterkill and subsequently fell away. The improvement of growth in 1945 was greatest in the

[3] See Hile (1941) for a more detailed discussion of this method of analysis.

pumpkinseed (*Lepomis gibbosus*) of Green Lake (79.2 percent) and the yellow perch (*Perca flavescens*) of Duck Lake (61.3 percent). The Duck Lake perch also exhibited the sharpest subsequent decline with growth below the premortality level in both 1946 and 1947. The decrease in the growth of the yellow perch of Green Lake was slight in 1946 (from 35.0 percent to 32.7 percent), but pronounced in 1947 (to 9.8 percent). After a large decrease from 79.2 percent in 1945 to 15.5 percent in 1946, the growth of the Green Lake pumpkinseed improved again in 1947 (to 39.1 percent).

TABLE 6.—*Percentage deviation of the growth of certain stocks of fish in different calendar years from the average for the period prior to the winterkill in the winter of 1944–1945*

Lake	Species	Before winterkill							After winterkill		
		1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Batteese..	Bluegill.....	+12.9	+ 7.0	−10.4	− 4.3	−11.8	+ 3.4	+ 3.4	+35.6	+ 4.2	.....
Goose....	Bluegill.....	.....	.....	−10.0	− 1.0	+15.0	− 2.8	− 1.2	+19.5	+29.0	.....
Goose....	Largemouth black bass..	.....	+ 7.5	+ 5.8	+ 7.5	− 1.0	− 8.0	−12.0	+ 0.5	−22.0	.....
Duck....	Perch.....	.....	.....	.....	+ 2.6	+11.4	− 4.0	−10.0	+61.3	− 2.3	−13.3
Green....	Perch.....	.....	− 9.6	−11.4	+ 2.7	+14.0	+ 4.0	+ 0.2	+35.0	+32.7	+ 9.8
Green....	Pumpkinseed .	.....	.....	− 8.9	+ 3.2	+ 8.5	− 0.5	− 2.3	+79.2	+15.5	+39.1

The curve for the Goose Lake bluegill differed from those just described in that growth did not decline in 1946 but rose to a still higher level (from 19.5 percent above the 1940–1944 mean in 1945 to 29.0 percent in 1946). The largemouth black bass of Goose Lake was one fish whose level of growth was lower following than preceding the winterkill.

The growth rates of all the fishes, except the bluegill in Batteese Lake, were approximately at the state average prior to the winterkill. The increase following the mortality brought the average size of the fishes, especially those of the younger age groups, to levels exceeding the state average. The effects of the improved conditions for growth were less obvious among the older fish, which were at an age when the annual increments were relatively small.

Several other species from these lakes and from other lakes which were excluded because data were inadequate for a detailed analysis of the percentage changes followed the same general trend.

The results of this study suggest that when an improvement of growth does follow a winterkill the benefit is only temporary. It is necessary therefore to question the value of any attempts to relieve stunting of fishes by the removal of part of the population. If the effects are to last only 1 or 2 years, the reduction of the population density does not seem practical as a management technique.

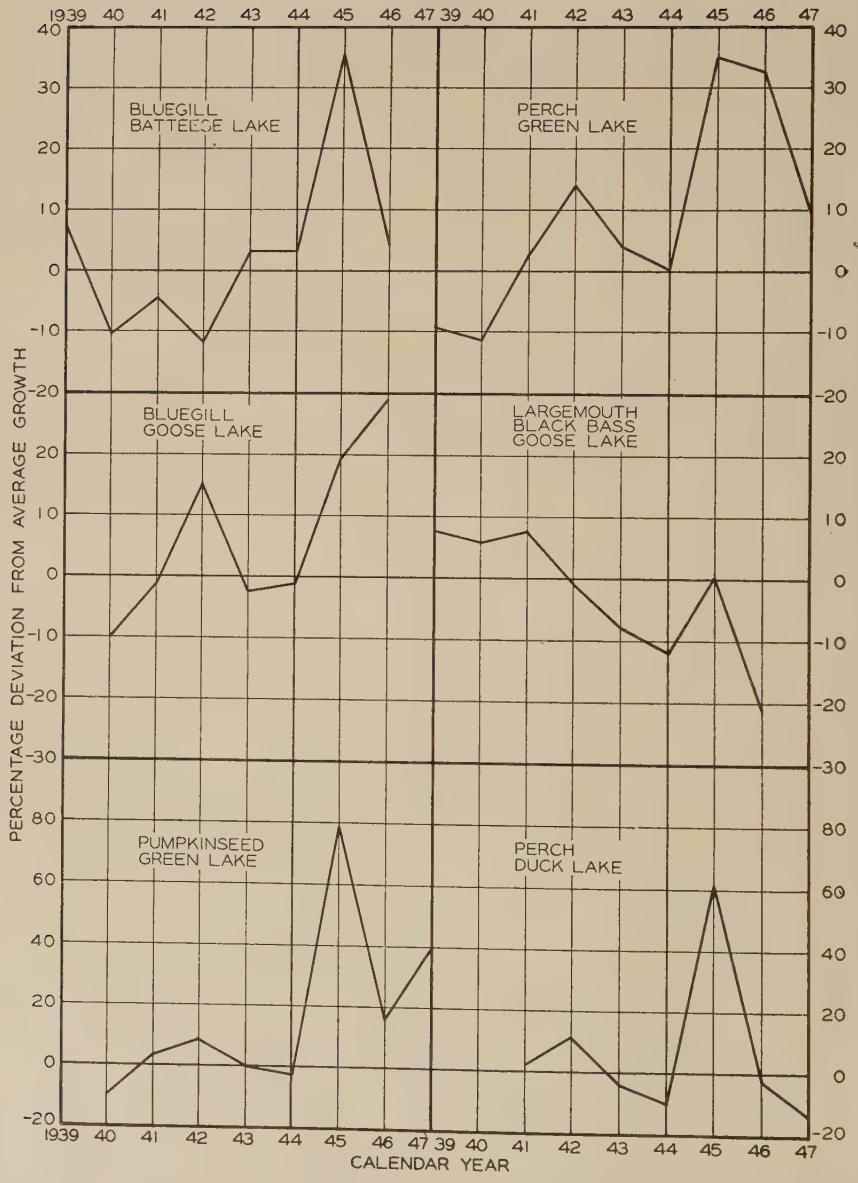

FIGURE 1.—Annual percentage deviation of the growth of four species of fish from four lakes from the average of the period prior to the mortality. The heavy vertical ruling at 1944 indicates the last year of growth before the winterkill. (The data for the Batteese Lake bluegill in 1938 were not used in order to reduce the size of the figure).

The question arises also as to just how many fish must be removed in order to benefit even temporarily the growth rate of those remaining. In Batteese Lake, the elimination of 165,000 bluegills (1,650 per acre) was inadequate because the subsequent rate of growth, though improved, was still below the average for the state. Yet in Green Lake the much smaller loss of 16,852 bluegills (215 per acre) apparently destroyed the entire population, because for 2 years following the kill no bluegills were taken. A planting of 50 adults has reestablished the species, and the bluegills at present are maintaining average growth. Largemouth black bass had to be restocked after the loss of 1,512 fish (19 per acre) apparently eliminated this species from the lake. The loss of 41,922 bluegills (98 per acre) in Goose Lake was followed by a slight improvement in the growth rate of the remaining fish, but the death of 13,922 largemouth black bass (33 per acre) did not raise the growth of this species beyond the pre-mortality level.

It appears therefore to be necessary to determine the population within a lake and the rate of growth of the several species before any consideration can be given as to whether or not an attempt at reduction of the stock should be undertaken. Experiments must be conducted under various conditions to ascertain what percentage of the population must be eliminated to produce an increased growth.

Careful consideration should be given also to the species composition. Although exact figures are not available, it is known that in the lakes observed in the course of this study the different species were not destroyed at the same rate. Mortality of rough fish was less than that of game species. As a result the rough fish, having the advantage of larger numbers, have reproduced to such an extent that they now dominate certain lakes. The drop in the rate of growth following the large increase immediately after the kill may be due to competition for food, with the rough fish the apparent winners. The great increase in lake chub suckers in Green Lake provides a good example of this point. At the time of the kill a count of 5,418 chub suckers was made. When gill nets were operated in the lake during May 1945, 285 chub suckers were caught, but in May 1947, 584 were taken in similar gear and fishing time. Yellow and brown bullheads (*Ameiurus natalis* and *A. nebulosus*) also appeared to be relatively more abundant than before the mortality. Our observations agree with those of Bennett (1948) who found a lower mortality for rough fish than for game species during a winterkill in Gale Lake, Illinois in 1944–1945, and stated that the rough fish predominated when the stock was destroyed by poisoning in 1946.

It may be that the need in many of the waters is for the reduction of the stocks of particular species rather than the destruction of a certain percentage of all fish. If the bluegills, for example, are stunted perhaps the best technique would be to remove as many of them as possible. Thus the predatory species may be given a chance to gain control and keep the future generations of bluegills at a more satisfactory level of abundance. It is planned to conduct experiments to develop techniques for a selective de-

struction within populations. During the midsummer period many of the larger fish of some species are in deeper water, while the young-of-the-year and yearling fish are in the shoal water. By treating the shallows with poison it may be possible to reduce the population sufficiently to bring about a desirable change in growth and still leave the larger fish intact to control the next brood of young.

Restocking with suitable predatory species following the reduction of the stock might prove useful. This technique will be tried in an experiment in which the first step is to be the removal of part of the bluegills from a Michigan Lake. Following this reduction, a planting of yearling large-mouth black bass will be made to determine whether the addition of this predator can keep the bluegills under control and permit them to maintain an average rate of growth.

One of our greatest weaknesses at the present time is the lack of an accurate method of determining the existing fish population of a lake. If we are to manage the stocks, we must know the approximate numbers of fish and their species composition. Until we have that type of information we shall not understand why certain lakes produce good fishing while others yield poor fishing. Without that understanding attempts at improvement have a good chance of being completely ineffectual.

Studies of the lakes covered in this paper will be continued to detect changes which may occur from year to year, and to learn what effect future light or heavy kills may have on the fish population and rates of growth.

Literature Cited

Beckman, William C.

1941. Increased growth rate of rock bass, *Ambloplites rupestris* (Rafinesque), following reduction in density of the population. Trans. Am. Fish. Soc., Vol. 70 (1940), pp. 143–148.

1943. Further studies on the increased growth rate of the rock bass *Ambloplites rupestris* (Rafinesque), following the reduction in density of the population. Trans. Am. Fish. Soc., Vol. 72 (1942), pp. 72–78.

1949. The rate of growth and sex ratio for seven Michigan fishes. Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 63–81.

Bennett, George W.

1948. Winterkill of fishes in an Illinois Lake. Lake Management Reports, Ill. Nat. His. Surv., Biol. Note No. 19, 9 pp.

Hile, Ralph

1941. Age and growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in Nebish Lake, Wisconsin. Trans. Wis. Acad. Sci., Arts, and Lett., Vol. 33, pp. 189–337.

THE FISHERIES OF INDIA—PRESENT STATUS AND PROPOSED DEVELOPMENT

H. D. R. Iyengar

Watumull Foundation
Mysore, India

Abstract

A general survey of the fishing industry in India is given. Fishes of commercial importance are listed, along with fishing gear, and methods employed in fishing are briefly described. Mention is also made of the post-war development scheme as outlined in the policy of the Government of India.

Historical

Records of Indian fisheries date back to 1000 B.C. in the Vedas, religious books brought by the Aryans to India. These migrants to India were agriculturists and pisciculture was part of their enterprise. They pursued a policy of constructing artificial ponds and stocking them with fish. Some of their fishing methods persist in India even today. The introduction of the hook in fishing dates back to 800 B.C. It is referred to in the Vedas as the *badisha*. By 200 A.D. fishing with hook and long line was developed. In 400 A.D. fishing with live bait was practiced. An interesting poem in the Mahabharata, one of the great Indian epics, refers to the bait as follows: "When women see a man caught in the bonds of love they draw him like a fish that has followed the bait."

There was a period in the annals of Indian fishing when abstention from fish was widely preached. This was at the time of the Great Buddha. The practice was not adhered to and the preachings were futile. After the Buddhistic era, fishing with cormorants in the Indus valley began. An interesting explanation is offered for this method. Since the bird caught the fish and the people had no share of the sin of fishing, they did not offend the Buddhistic monasteries.

In the proceedings of this meeting, one of the members mentioned a fish rodeo in Texas where they are offering $75,000 in prizes. This reference brought to my memory the fish rodeos conducted by our ancient kings in which the prize was not dollars, but a bride. A fish was hung on the ceiling over a big vessel containing oil. The entrants had to look at the reflection of the fish in the oil and shoot the fish with an arrow. The man who hit the bullseye got the bride.

Following the advent of the British in India, fishery was given a scientific touch. The most outstanding contributor is Day, whose works may easily match those of the famous American ichthyologist D. S. Jordan.

India's Coast Line and Fishing Areas

India has a coast line of 3,200 miles and a total of 100,000 square miles of fishing area, of which only a small portion is exploited. The harbors are very few and far between and even though the coast line is studded with fishing villages, adequate havens for fishing boats are conspicuously absent. The 100- to 200-fathom contour is far offshore. Although on the east coast the distance seldom exceeds 20 miles, on the northwest coast it is up to 200 miles.

Inland permanent water areas cover over 50,000 square miles. In the Province of Bengal alone the inland fisheries have water surface of 2,500 square miles. Among our major rivers are: Brahmaputra, Ganges, Mahanadi, Godavari, Kistna, Cauvery, Narbada, and the Indus. Some of the rivers of North India are alpine fed, some are navigable and a few are highly turbulent. Our great inland lakes are at Manipur, Crisse, Sind, and Kashmir. In addition, India has a large system of tanks and artificial ponds. Almost every village has a pond.

The eustuarine fishing areas are in the delta regions of the major rivers, especially in the Ganges and Indus deltas. Thus the riparian areas are so extensive that the land is very well suited for high productivity of fish.

Fishing Gear

In the proceedings of the Society, reference has been made to the undeveloped status of the Philippine fishery. The same holds true for India. It has been mentioned also in remarks about Japan, that her extensive fishing fleet was the result of a great navy. The lack of navy up to last year may explain the status of India's fishing fleet. She had a total tonnage of 100,000 tons, with the biggest vessel of only 8,000 tons. The present Government has bought in six months over 200,000 tons of shipping. The coastal traffic in India was in the hands of foreign enterprises, to such an extent that the fishing industry has remained in a primitive state. In order to show how primitive conditions are, I would like to give an estimate of the number of native craft used by our fishermen.

The fishing craft of the east coast differs from that of the west coast of India because the east coast has heavier surf than the west coast. The vessels on the east coast are called catamarans and consist of four pieces of logs tied together to ride the surf. Those on the west coast are all wooden sail boats, about 5 to 10 tons in displacement.

The number of various types of craft are: wooden boats, 26 to 35 feet long and 5 to 8 feet in width, 3,585 (3,400 in west coast alone); canoes, 37,000; masula boats, 6,000; catamarans, 24,000. (23,000 in west coast alone).

Tackle and Nets

One hundred fifty types of fish nets including casting, gill, stake nets, and seines are found in India. The chief types of gear used are long lines

and fish traps. In the major ports large beach seines are used. Other tackle includes missile implements, spears, arrows and hooks of various and ingenious design.

Fish Marketing and Consumption

The annual catch has been estimated at something over 700,000 tons of fish, while the estimated need of the country is 7 million tons. The per capita consumption at the present is 3.4 pounds per annum, as compared to the 40 pounds per capita consumed in England or 15 pounds in the United States. This brief statement shows the need for increasing our fish production. Over 60 percent of India's population eats fish. When India has a more efficient system of transporting and marketing fish, the demand will be greater. Today the fish are consumed in the places where they are caught. Lack of adequate transportation causes 90 percent of the marine fish to be cured. The fishery departments of the various provincial governments have originated co-operatives by means of which they are distributing the fish to the population. This program in the future will be expanded to make fish available to the entire population.

Fish Curing

While most of the catch of fish is sun-dried and salted, some of it is pickled and brine-cured. In the pickling use may be made of such condiments as tamarind, cloves, cumin, aniseed, coriander, pepper, and chili. An attempt at fish canning made by the Government of Madras was given up for lack of demand traceable to prejudice against canned food in India. The liver-oil industry was first started in 1852. By 1941, Madras was producing 40,121 pounds of shark-oil, and by 1944, 63,000 pounds.

Sport Fishing

Sport fishing in India is practiced only by the privileged class. To quote Radcliffe, "the angler, pure and simple for the mere love of sport is hardly represented in the people of India." The best known fresh-water sport fish in India is the *mahaseer* which experienced anglers believe affords more sport than the salmon. The fish is tough to land and weighs on an average between 80 and 100 pounds. Those that are interested may read the book "Rod in India" by H. S. Thomas. Another sport fish that has been introduced in some of our colder streams is the rainbow trout.

Fishes of Commercial Importance

India abounds in a great variety of fish. There are 351 genera and 1,418 species of fish, of which only 200 species are of any economic importance. The fishes of great economic importance are given in the following lists.

MARINE

Cybium
Stromateus (Pomfret)
Polynemus (India salmon)
Sardinella longiceps
Scomber (Mackerel)
Arius (Catfish)
Caranx (Horse mackerel)
Bonito
Chanos salmoneus (Milkfish)
Mugil (Mullets)
Cypselurus (Flyingfish)
Cynoglossus (Sole)
Lutjanus (Snapper)
Serranus (Blue perch)
Trygon (Rays)
Carcharias (Sharks)
Pristis
Hemiramphus

ESTUARINE FISHES

Lates calcarifer
Etroplus
Clupea ilisha

FRESH-WATER FISHES

Anabas
Osphronemus goramy
Ophiocephalus
Cirrhanea mrigala
Carps
Catfishes
Labeo
Pseudecheneis [1]
Glyptosternon [1]
Schizothorax [1]
Exostoma [1]
Notopterus

HOLOTHURIANS [2]

Holothuria sabra
H. mormorata
H. edulis
H. atra

CRUSTACEANS

Peneopsis monoceros (Prawn)
Neptunus gladiator (Crab)
Goniosoma natator (Crab)
Xantho scabberus (Crab)
Thenus orientalis (Lobster)

MOLLUSKS

Margaritifera vulgaris [3]
Ostrea
Triton
Voluta
Rostellaria
Turbonella
Area
Loligo (Squid)

Other than the species listed the sperm whales, dugong, and turtles are commercially important.

[1] Important hill-stream species.
[2] Used for preparation of trepang, exported to China.
[3] Pearl oyster.

Plans for Post-War Development

A 5-year plan has been drawn up by Dr. Baini Prashad, fisheries development advisor to the Government of India, under which groups of students are sent to foreign countries to study advanced methods of the fishing industry. Many of us are here now under that plan.

Fishery research has been instituted in two newly opened research stations, one for marine and another for fresh-water fisheries. These stations are in addition to the research laboratories at Krusadai, Madras, Bengal, and Bombay. The federal, provincial, and state governments are lending full support to the development of Indian fisheries and the Food and Agricultural Organization of the United Nations is another agency to which India looks for assistance.

Private individuals have been given assistance in the purchase of boats, gear, and other needs for exploiting the fishery. Schools for fishermen have been started to spread education and raise their standard of living. Their primitive and chronically indebted state needs a good deal of attention. Given the right stimulus and up-to-date tools of the trade, there is every hope for the establishment of a highly productive fishery in India. In a country with an alarmingly high proportion of undernourished people the need for making use of the natural resources is great. Our leaders are fully aware of this need.

Some scientific journals that often publish fishery papers may be mentioned here. The Bombay Natural History Magazine is devoted to fish and game. Records of the Indian museum, The Current Science, and a few University publications are some of our leading scientific journals. The annual convention of the Indian Science Congress maintains a section for zoology and fisheries and affords opportunity for Indian scientists to meet and exchange ideas, just as the American Fisheries Society does here.

Some of our leading ichthyologists who have contributed to the development of the fisheries are: Dr. Baini Prasad, Dr. S. L. Hora, Dr. Sunder Raj, Dr. Bhatia, Dr. A. Das, and Dr. B. S. Bhimachar. All of these men are still directing the development of Indian fisheries on sound and scientific lines.

THE APPARENT THRESHOLDS OF TOXICITY TO *DAPHNIA MAGNA* FOR CHLORIDES OF VARIOUS METALS WHEN ADDED TO LAKE ERIE WATER

BERTIL G. ANDERSON

Franz Theodore Stone Laboratory, The Ohio State University
Put-in-Bay, Ohio

AND

Department of Biology, West Virginia University
Morgantown, West Virginia

CONTENTS

	Page
Abstract	97
Introduction	97
Experimental procedure	97
Determination of toxicity thresholds and comparisons with earlier findings	99
Sodium chloride	99
Calcium chloride	101
Comparative toxicity of sodium and calcium salts	103
Magnesium chloride	103
Potassium chloride	104
Ammonium chloride	104
Strontium chloride	105
pH changes and precipitates	105
Stannic chloride	105
Manganese dichloride	105
Ferrous chloride	105
Lithium chloride	106
Antimony trichloride	106
Barium chloride	106
Stannous chloride	106
Ferric chloride	106
Aluminum chloride	107
Cobalt chloride	107
Chromic chloride	107
Nickel chloride	108
Lead chloride	108
Zinc chloride	109
Cupric chloride and cupric ammonium chloride	109
Silver nitrate	110
Mercuric chloride	110
Cadmium chloride	110
Comments on the conduct, interpretation, and practical application of toxicity experiments	110
Acknowledgement	112
Literature cited	112

Abstract

The apparent threshold concentrations of toxicity to *Daphnia magna* are presented for 25 cations when added to Lake Erie water. Various factors such as the specific toxic actions of the cations, high acidities, excessive osmotic pressures, and precipitates operated to kill daphnids when the salts used were above the thresholds. When factors other than the specific toxic actions may have been responsible for death at threshold concentrations they are described. The thresholds presented are compared with those found by other investigators for *Daphnia* and other animals, especially fish. In general the *Daphnia* and related forms are more susceptible to cations than are fish.

Ecdysis is a critical period in the life of *Daphnia,* particularly in the presence of certain salts. Various explanations are advanced to account for this fact. Since daphnids are more susceptible at molting it is essential that exposure periods be long enough to provide sufficient time for all the experimental animals to molt when threshold concentrations of toxicity are determined. This finding is expected to apply in toxicity experiments with other arthropods.

That the maximum safe concentrations in which wastes may be permitted to enter natural waters are not likely to exceed the threshold concentrations to *Daphnia* is discussed.

Introduction

Adequate programs for the abatement of pollution require that effluents which are admitted to lakes and streams should be innocuous to the organisms in the receiving waters. As a first step in the development of such programs it is necessary to ascertain the reactions of aquatic organisms to the substances found in effluents. Our present knowledge of the tolerances of aquatic animals to substances found in industrial wastes is fragmentary at best (Anderson, 1946). Inasmuch as metal salts are found in many industrial wastes and all salts are harmful when they are in high concentrations, a series of experiments has been carried out to determine the apparent thresholds of toxicity for the chlorides of various metals when *Daphnia magna* is employed as the test animal.

Many of the advantages of using *Daphnia magna* as a test animal for the determination of the toxicity of industrial wastes were pointed out by Anderson (1944). These advantages were demonstrated further by the report of Anderson, Chandler, Andrews, and Jahoda (1948) on the evaluation of several aquatic invertebrates as assay organisms for the determination of the toxicity of industrial wastes. In the above report it was concluded that the susceptibility of *Daphnia magna* to toxic substances was representative of the susceptibility of predominant zooplankters to toxic substances.

Experimental Procedure

The methods used in securing the results presented below were identical with those employed previously (Anderson, 1944 and 1946) except that the thresholds were estimated on the basis of concentration-immobilization time curves for exposures of 64 hours. The thresholds given in the earlier paper

(Anderson, 1944) were determined from concentration-immobilization time curves for exposure periods of 16 hours. Subsequently, 16-hour exposure periods were found inadequate and the time of exposure was increased to 48 hours (Anderson, 1946). Sixteen-hour exposures were inadequate because one half of the experimental animals did not reach the molting stage within that time and molting is a critical phase in the life of daphnids.

That half of the experimental animals did not reach the molting stage during the 16-hour exposure period is readily explained. To obtain young animals for the toxicity experiments a stock of individually reared females was maintained. Eight hours before each experiment all the young were removed from the stock cultures. At the beginning of the experiment all the young were again removed and these young were segregated for use as experimental animals. Inasmuch as these animals were released over an 8-hour period they were not more than 8 hours old with a medium age of 4 hours at the time of segregation. In other words at the beginning of an experiment the animals were 4 ± 4 hr. old. According to Anderson and Jenkins (1942) *Daphnia magna* molt for the first time some 20 hours after their release from the mothers when reared at 25° C. At the end of a 16-hour exposure the experimental animals had reached an age of 20 ± 4 hours (4 ± 4 hours $+ 16$ hours $= 20 \pm 4$ hours) so that half the animals had passed the time for molting and the other half had not yet molted.

Banta (1939) stated that molting is a critical period for cladocerans and other arthropods. In toxicity experiments this appears to be true for *Daphnia magna,* especially in the presence of certain substances. (Note the pronounced inflections in the region of 16 hours in the concentration-immobilization time curves for strontium chloride, chromic chloride, and zinc chloride in Figures 1 and 2. Apparently the daphnids were more susceptible to these substances at the time of molting than they were before that time.) Exposure periods, therefore, should be of long enough duration to allow time for all of the experimental animals to pass the molting stage. The 64-hour exposure for the experiments described here was more than sufficient to allow all of the animals to pass both the first and second molting stages. There is no indication, however, that the daphnids were more susceptible during the second molt than they were during the first.

The fact that 16-hour exposure periods are inadequate does not invalidate the results presented by Anderson (1944). Experiments of greater duration have been carried out for many of the substances listed in that paper. In all cases close agreement has been obtained for the data on concentration-immobilization time relationships in both the earlier and later experiments for the periods up to 16 hours, which is as long as the earlier experiments were run. In the absence of results based on longer exposure periods the thresholds presented in the earlier paper (Anderson, 1944) represent the maximum concentrations in which *Daphnia magna* are likely to survive. Those threshold values may be revised downward as a result of experiments involving longer exposure times but they are not likely to be exceeded.

The thresholds of toxicity for chlorides of various metals as determined on the basis of the results of the present experiments are given in Table 1. Concentration-immobilization time curves for some of the chlorides are shown in Figures 1 and 2. In Table 1 the values preceded by either $<$ or $<<$ are not true threshold concentrations since the concentration-immobilization time curves for the salts so designated had not reached their vertical asymptotes at 64 hours. The threshold concentration for a salt with $<$ might be slightly lower than the value given, possibly by 10 percent, if the trend of the curve continued unchanged. Cupric chloride is an example, the curve for which is shown in Figure 2. The threshold concentration for a salt with $<<$ might be considerably lower than the value given if the trend of the curve at 64 hours continued unchanged. Chromic chloride is an example and its curve also is shown in Figure 2. A value that is not preceded by $<$ or $<<$ may not be a true threshold concentration. When both $<$ and $<<$ are lacking the concentration-immobilization time curve had apparently reached its vertical asymptote in 64 hours or less but experiments of greater duration might yield lower values.

The literature on the effects of salts on aquatic animals is enormous. Much of the experimental work has been done with distilled water as the diluent. The results of experiments with distilled water as the diluent are of little if any significance to pollution-abatement programs since distilled water itself is toxic to many animals (Anderson, 1944 and 1946). A considerable number of investigations has been carried out in which the exposure periods have been relatively short. The value of such experiments is questionable as far as pollution abatement is concerned since many substances that are found in effluents remain active for long periods after entering the receiving waters. In the discussions which follow, the results of the present experiments will be compared with those obtained under comparable conditions. The results will be considered in the order of decreasing toxicity thresholds as given in Table 1.

Determination of Toxicity Thresholds and Comparisons with Earlier Findings

In this section all statements relative to threshold concentrations refer to Table I; consequently citations of this table are omitted in the several subsections. References are made, however, to the figures that include immobilization time curves for substance discussed.

Sodium Chloride.—Sodium chloride was the least toxic of all chlorides (Figs. 1 and 2). Its toxicity threshold was estimated at 0.063 molar (3,680 p.p.m.). This value is considerably lower than that reported by Anderson (1944) when the thresholds were calculated on the basis of a 16-hour exposure period and is somewhat lower than that based on a 48-hour exposure period (Anderson, 1946).

Ellis (1937) listed the results of several investigators who have subjected fish to sodium chloride in various diluents including distilled as well as natural waters. When comparisons are restricted to results obtained with

natural waters one finds that fish tolerate much higher concentrations than *Daphnia*. Ellis found that goldfish (*Carassius auratus*) were unharmed by 5,000 p.p.m. (0.085 molar) in Mississippi River water but that they survived 10 days or less in 10,000 p.p.m. (0.171 molar). Recently Edmister and Gray (1948) reported that fry of yellow pikeperch (*Stizostedion v. vitreum*) and lake whitefish (*Coregonus clupeaformis*) were immobilized by 0.066 molar (3,859 p.p.m.) and 0.282 molar (16,500 p.p.m.), respectively, in Lake Erie water but survived in lower concentrations. The value for yellow pikeperch fry approximates that for *Daphnia*.

TABLE 1.—*Threshold concentrations for the immobilization of* Daphnia magna *by substances when added to Lake Erie water*

[See text for explanation of symbols < and << preceding certain figures]

Substances	Formula	Molarity[1]	p.p.m.[1]
Sodium chloride	$NaCl$	0.063	3,680
Calcium chloride	$CaCl_2$	0.0083	920
Magnesium chloride	$MgCl_2$	0.0078	740
Potassium chloride	KCl	0.0058	432
Ammonium chloride	NH_4Cl	0.0017	91
Strontium chloride	$SrCl_2$	0.00072	114
Stannic chloride	$SnCl_4$	0.00056	146
Manganese chloride	$MnCl_2$	0.0004	50
Ferrous chloride	$FeCl_2$	<<0.0003	<<38
Lithium chloride	$LiCl$	<0.00017	<7.2
Antimony trichloride	$SbCl_3$	0.00016	37
Barium chloride	$BaCl_2$	0.00014	29
Stannous chloride	$SnCl_2$	<<0.00013	<<25
Ferric chloride	$FeCl_3$	<0.00011	<18
Aluminum chloride	$AlCl_3$	<0.00005	<6.7
Cobalt chloride	$CoCl_2$	<0.000024	<3.1
Chromic chloride	$CrCl_3$	<<0.000023	<<3.6
Nickel chloride	$NiCl_2$	<0.0000054	<0.7
Lead chloride	$PbCl_2$	0.0000045	1.25
Zinc chloride	$ZnCl_2$	<<0.0000011	<<0.15
Cupric chloride	$CuCl_2$	0.0000002	0.027
Cupric ammonium chloride	$CuCl_2.2NH_4Cl$	0.00000016	0.039
Silver nitrate	$AgNO_3$	0.00000003	0.0051
Mercuric chloride	$HgCl_2$	<0.000000022	<0.006
Cadmium chloride	$CdCl_2$	<<0.000000014	<<0.0026

[1] On the basis of the formula given

The results of other investigators on plankton Crustacea are comparable to those of the present experiments when the conditions were equivalent. Naumann (1934a) found that *Daphnia magna* were immobilized by 0.05 molar solutions of sodium chloride in both soft and hard waters. Warren (1899) reported that 0.5 percent (0.085 molar) was innocuous to some individual *Daphnia magna* but he did not mention the source of the diluent water. He found that 0.55 percent (0.094 molar) was lethal to all individuals. Fowler (1931) determined that *Daphnia longispina* survived for 66 hours in 0.05 molar in a well water. Ramult (1925) reported that *Daphnia pulex* failed to develop in 0.1 molar but that some developed in 0.05 molar in a pond water. He also wrote that *Ceriodaphnia laticaudata*

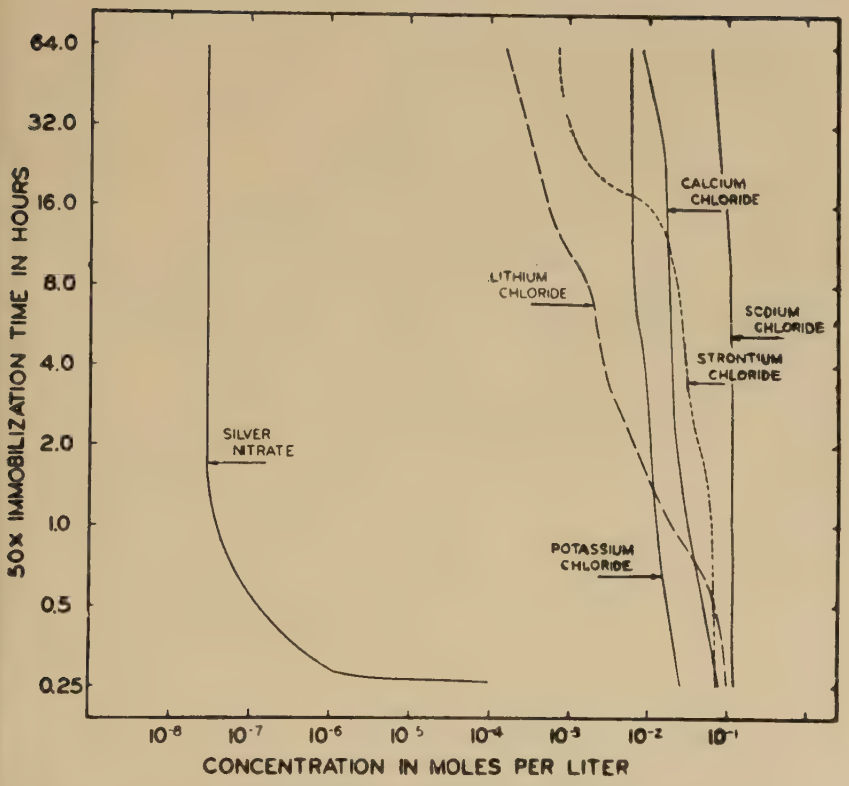

FIGURE 1.—Relation of immobilization times for *Daphnia magna* to the concentrations of sodium chloride, calcium chloride, potassium chloride, strontium chloride, lithium chloride, and silver nitrate.

adults were weakened by 0.05 molar but that *Pleuroxus aduncus* tolerated this concentration. Anderson, Chandler, Andrews, and Jahoda (1948) carried out a series of experiments on predominant plankton Crustacea and reported that *Leptodora kindtii, Cyclops vernalis,* and *Diaptomus oregonensis* were immobilized by 0.063 molar, 0.104 molar, and 0.052 molar, respectively, in Lake Erie water. On the basis of the above evidence, one may conclude that concentrations of sodium chloride above 0.05 molar (approximately 3,000 p.p.m.) are deleterious to Crustacea and some fish fry. For complete safety the sodium chloride level might well be held below 0.035 molar (2,000 p.p.m.).

Calcium Chloride.—Calcium chloride was second in the scale of increasing toxicity of the chlorides investigated. Its threshold of toxicity was 0.0083 molar (920 p.p.m.). This value is about two-thirds that reported by Anderson (1944) on the basis of an exposure period of 16 hours. Ellis

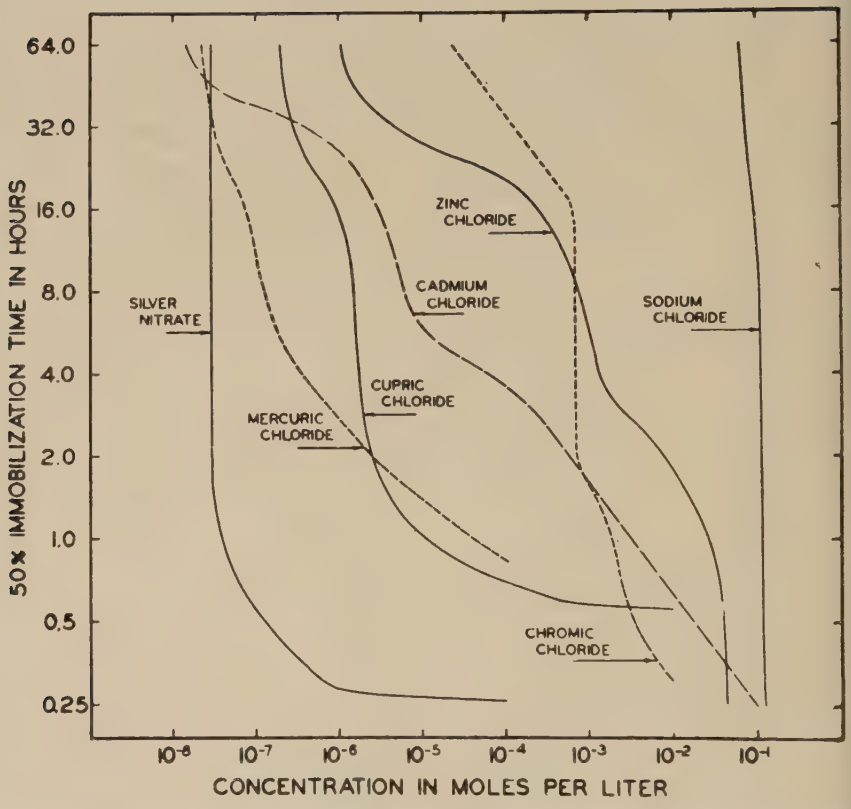

FIGURE 2.—Relation of immobilization times for *Daphnia magna* to the concentrations of sodium chloride, chromic chloride, zinc chloride, cupric chloride, silver nitrate, mercuric chloride, and cadmium chloride.

(1937) referred to only one set of experiments on fish with calcium chloride, where a natural water may have been the diluent and in which golden shiners (*Notemigonus crysoleucas*) were killed by 5,000 p.p.m. (0.045 molar) in 143 hours. Edmister and Gray (1948) reported that fry of yellow pikeperch and whitefish were immobilized by 0.108 molar (12,060 p.p.m.) and 0.199 molar (22,080 p.p.m.), respectively, but survived lower concentrations in Lake Erie water.

Crustaceans tolerate much less calcium chloride than fish do, Naumann (1934a) stated that 0.0066 molar in a soft water was without effect on *Daphnia magna* in 24 hours, but that 0.0165 molar produced a weakening. In a hard water, 0.0165 molar was without effect but 0.033 molar immobilized *Daphnia magna*. Fowler (1931) reported that 0.05 molar killed *Daphnia longispina* in 41 hours when he used a well water as the diluent.

Ramult (1925) found that 0.0167 molar in a pond water caused a weakening of *Daphnia pulex* adults by the second day and inhibited development of the eggs. Anderson, Chandler, Andrews, and Jahoda (1948) gave 0.0156 molar (1,730 p.p.m.) and 0.013 molar (1,440 p.p.m.) as the thresholds to *Cyclops vernalis* and *Megacyclops leuckarti,* respectively.

Comparative Toxicity of Sodium and Calcium Salts.—Sodium chloride was one-eighth as toxic as calcium chloride to *Daphnia magna* when Lake Erie water was the diluent and the concentrations were expressed in moles. Calcium ions would therefore be said to be eight times as toxic to *Daphnia* as sodium ions. However no general rule can be laid down on the relative toxicity of calcium and sodium salts that would hold for all species. Whitefish fry tolerated about two-thirds as much calcium chloride, as sodium chloride, while yellow pikeperch fry tolerated 1 2/3 as much calcium chloride as sodium chloride, when concentrations were expressed in terms of molarity (Edmister and Gray, 1948). According to Jones (1939) the threespine stickleback (*Gasterosteus aculeatus*) tolerated just as much of sodium nitrate as of calcium nitrate (0.0217 molar $NaNO_3$ and 0.02 molar $Ca(NO_3)_2$ in Aberystwyth tap water. In this case the nitrate ion may have been a lethal factor. Meek (1916) referring to *Gasterosteus aculeatus* said, "It is as much at home in salt water as fresh, and may be changed from one to the other with impunity." The sodium chloride content of sea water is much greater than 0.0217 molar, the concentration which Jones found to be the threshold for sodium nitrate in Aberystwyth tap water, a soft water. Indeed, Jones (1940) stated that, "The nitrates of sodium, magnesium, calcium, and strontium are somewhat more toxic than the chlorides apparently because the nitrate ion has a greater lethal activity than the chloride ion," when he used *Polycelis nigra* as the experimental animal and distilled water as the diluent. *Daphnia magna* also tolerated slightly more sodium chloride than sodium nitrate (Anderson, 1946). From the above discussion one may conclude that some aquatic animals tolerate more sodium ions than they do calcium ions and others tolerate more calcium ions than they do sodium ions. No general rule appears to hold concerning the relative toxicities of sodium and calcium. Further, in studies of the comparative toxicity of the metals, the chlorides are preferable to the nitrates because of the lower toxicity of the chlorides.

Magnesium Chloride.—Magnesium chloride was somewhat more toxic than calcium chloride to *Daphnia magna,* but the difference is so slight that it may not be significant. The threshold was 0.0078 molar (740 p.p.m.). Hutchinson (1933) gave the following tolerance limits for survival and reproduction for Cladocera: *Daphnia magna,* 0.01 molar; *Daphnia thomsoni,* 0.00125 molar; *Daphnia* pulex, 0.005 molar; *Daphnia longispina* (clone 1) 0.0025 molar; *Daphnia longispina* (clone 2) 0.00125 molar; *Ceriodaphnia reticulata,* 0.0025 molar; and *Moina macrocopa,* 0.0075 molar, when he used a pond water as the diluent. Naumann (1934a) stated that 0.0165 molar magnesium chloride in both hard and soft waters was unfavorable for *Daphnia magna.* Fowler (1931) found that *Daphnia longispina* sur-

vived 0.037 molar magnesium chloride in well water for only 43 hours. Ellis (1937) listed the results of experiments with magnesium chloride in distilled water on fish but none where natural waters were employed as the diluent. In two experiments of the three cited by Ellis with distilled water the fish were much more tolerant than the animals discussed above. Jones (1939) gave 0.0123 molar as the threshold for magnisium nitrate to the three-spine stickleback when this salt was dissolved in Aberystwyth tap water. The stickleback appears to be somewhat more tolerant than do the Cladocera.

Potassium Chloride.—Of the chlorides tested, potassium chloride proved to be fourth in the scale of increasing toxicity. Its threshold was 0.0058 molar (432 p.p.m.). Naumann (1934a) found that 0.01 molar immobilized *Daphnia magna* in soft water and irritated those in hard water. Fowler (1931) reported that *Daphnia longispina* survived less than 7 hours in 0.025 molar in well water. Baylor (1942) gave 0.005 molar in aerated, non-chlorinated tap (well?) water as "sub-threshold" for effect on the heart beat of *Daphnia magna.* He found that 0.01 molar inhibited the heart to a slight extent but his exposure times were less than 2 hours. Ramult (1925) stated that 0.0167 molar in pond water killed *Daphnia pulex* adults and prevented the eggs from developing but that 0.0083 molar was without effect. Ellis (1937) listed no experiments with potassium chloride in natural waters but gave results for potassium nitrate and potassium sulfate. In tap water 1,203 p.p.m. (0.012 molar) potassium nitrate and 869 p.p.m. (0.010 normal) potassium sulfate killed bluegills (*Lepomis macrochirus*) in 15 days and 4 days, respectively. Jones (1939) gave 0.00127 molar as the threshold for killing the threespine stickleback by potassium nitrate in Aberystwyth tap water. In general, potassium salts appear to be twice as toxic to cladocerans as they are to fish.

Ammonium Chloride.—Although ammonium chloride is not a metal salt, it was included in this study because it is a common inorganic chloride and is often found in industrial wastes. Ammonium chloride immobilized *Daphnia magna* in concentrations above 0.0017 molar (91 p.p.m.) in Lake Erie water. On the basis of 16-hour exposures, Anderson (1944) had found 0.0025 molar to be the threshold. Naumann (1934a) reported that 0.01 molar in soft water was without effect on *Daphnia magna* but 0.025 molar immobilized them. In hard water 0.01 molar was toxic. Chipman (1934) declared that 0.01 normal ammonium chloride killed 50 percent of his *Daphnia magna* after a 6-hour exposure. Chipman also found that amphipods died after a 2-hour exposure in 0.005 normal ammonium chloride. Goldfish survived for 360 hours in 0.002 normal ammonium chloride and in 0.0015 normal ammonium sulfate but were immobilized in 0.004 normal ammonium sulfate and in 0.005 normal ammonium chloride (Chipman, 1934). Ellis (1937) pointed out that as little as 268 p.p.m. (0.005 molar) ammonium chloride in hard water killed goldfish in 6 days. He also gave the results of other experiments where higher concentrations were lethal. For ammonium sulfate in tap water he wrote that 66 p.p.m. (0.001 normal)

was found to kill bluegills and that 264 p.p.m. (0.004 normal) in tap water killed goldfish in 6 days or less. Ellis declared that 48 p.p.m. (0.001 normal) ammonium carbonate in hard water killed goldfish in 6 days. Chipman (1934) reported that the toxicity of ammonium salts increased with a rise in pH and therefore reasoned that the toxicity of ammoniumm salts varied with the concentration of undissociated ammonia in solution. Fish and crustaceans appear to be equally vulnerable to ammonium salts.

Strontium Chloride.—Strontium chloride was 10 times as toxic to *Daphnia magna* as was magnesium chloride or calcium chloride. The toxicity threshold for strontium chloride was 0.00072 molar. Ellis (1937) referred to no work on strontium salts with natural water as the diluent. Jones (1939) found that 0.0137 molar strontium nitrate in Aberystwyth tap water was the threshold for the threespine stickleback which value is somewhat higher than that for magnesium nitrate and two-thirds the value for calcium nitrate. *Daphnia magna* is much more sensitive to strontium than is the stickleback.

pH Changes and Precipitates.—The chlorides of sodium, calcium, magnesium, potassium, ammonia, and strontium do not produce precipitates when added to Lake Erie water. Neither do they alter markedly the hydrogen-ion concentration. The pH of Lake Erie water in the vicinity of Put-in-Bay was 8.2 to 8.4. Many of the salts which will be discussed below produce precipitates when added to Lake Erie water and/or alter the hydrogen-ion concentration. When either reaction occurred mention will be made of it in the discussions which follow. If no mention is made of the formation of precipitates or of a change in the hydrogen-ion concentration, noticeable precipitates did not form and the changes of the hydrogen-ion concentration were regarded as insignificant.

Stannic Chloride.—Stannic chloride was almost completely hydrolyzed on being added to Lake Erie Water. The pH of 0.2 molar stannic chloride was 0.2. On dilution a precipitate formed and the pH increased. The threshold for stannic chloride was 0.00056 molar. At this concentration there was a considerable amount of precipitate and the pH was approximately 6. The threshold may have been dependent on the hydrogen-ion concentration since solutions with a pH below 6 are rapidly lethal to *Daphnia magna* (Anderson, 1944). The precipitate may also have been a factor since it would act mechanically by obstructing the actions of *Daphnia.*

Manganese Dichloride.—The threshold concentration for manganese dichloride was 0.004 molar. When this salt was added to Lake Erie water the solution became slightly turbid in concentrations above 0.005 molar but was clear in lower concentrations. Jones (1939) reported that the threespine stickleback died in all concentrations of manganous nitrate above 0.000728 molar in Aberystwyth tap water.

Ferrous Chloride.—Ferrous chloride immobilized *Daphnia magna* in concentrations above 0.0003 molar. Additions of ferrous chloride to Lake Erie water caused precipitates. The pH values of all solutions above 0.0005

molar were less than 7. Since the toxicity threshold was below this value, the threshold was not influenced by the acidity of the solution. Ellis (1937) reported that 1,000 p.p.m. (0.0079 molar) in hard water killed goldfish in less than 10 hours but 100 p.p.m. (0.00079 molar) was apparently not harmful in 96 hours. Jones (1939) stated that ferrous sulfate became very rapidly transformed into ferric salts and was fatal because of the acidity produced. According to Jones, the threespine stickleback survived in solutions of pH 5.

Lithium Chloride.—Lithium chloride was the most toxic of all the chlorides of the alkali metals studied in the present experiments. The threshold for lithium chloride was 0.00017 molar.

Antimony Trichloride.—Antimony trichloride yielded a toxicity threshold of 0.00016 molar. In concentrations of 0.00125 molar and greater a precipitate formed. The 0.00125 molar solution was acid with a pH of 2.9. At 0.000372 molar the pH was 8.1 and no precipitate was noted.

Barium Chloride.—The toxicity threshold for barium chloride was 0.00014 molar or approximately the same as that for antimony trichloride. Barium chloride concentrations above 0.0016 molar in Lake Erie water had precipitates but below 0.00032 molar no precipitate was discernable so that a precipitate was not a limiting factor at the toxicity threshold. Jones (1939) found that 0.0029 molar barium nitrate in Aberystwyth tap water was the threshold for the threespine stickleback.

Stannous Chloride.—Stannous chloride was four times as toxic as stannic chloride. The threshold for stannous chloride was 0.00013 molar. Like stannic chloride, stannous chloride caused a precipitate in Lake Erie water and it also increased the hydrogen-ion concentration. As might be expected equimolar concentrations of stannous chloride did not reduce the pH as much as stannic chloride. The threshold for stannous chloride was not dependent on hydrogen-ion concentration since it was toxic at a pH of 7.8. The turbidity, however, may have been a contributing factor in immobilizing the *Daphnia* in concentrations above the threshold. Ellis (1937) reported that 1,000 p.p.m. (0.0053 molar) stannous chloride in hard water killed goldfish in 4 to 5 hours.

Ferric Chloride.—The threshold for ferric chloride was 0.00011 molar, which is somewhat lower than that for ferrous chloride. Anderson (1944) listed the threshold for ferric chloride as 0.0008 molar (130 p.p.m.) on the basis of a 16-hour exposure. If in the present experiments, the threshold had been determined on the basis of a 16-hour exposure period, it would have been estimated at 0.00063 molar, but the concentration-immobilization time curve is inflected at 16 hours in the same manner as the curve for chromic chloride shown in Figure 2. The threshold for ferric chloride as given in 1944 must be superceded by the new value reported above. In concentrations above 0.001 molar the solutions of ferric chloride were clear and their pH values below 3.5. In solutions with concentrations less than 0.001 molar a precipitate formed. Solutions with concentrations of 0.0005 molar and less had a pH of 7 or higher. Ellis (1937) found that 100 p.p.m.

(0.00062 molar) ferric chloride in very soft water killed goldfish in less than 90 minutes, but in hard water the same concentration was not detrimental in 96 hours. Jones (1939) found that ferric chloride in a concentration of 1.2 p.p.m. Fe (0.000021 molar) in Aberystwyth tap water killed threespine sticklebacks in six days. The pH of this solution was 4.8. In a ferric chloride solution containing 1.0 p.p.m. Fe (0.000018 molar) the sticklebacks survived ten days. The pH of the latter solution was 5.0. Jones attributed the toxicity of ferric chloride to the acidity of the solution. On the basis of the results presented above for Lake Erie water one might assume that in Aberystwyth tap water the toxicity threshold for iron was masked by the acidity. Were the acidity neutralized a definite threshold might have been determined for the ferric ion which would be higher than that indicated by Jones.

Aluminum Chloride.—Aluminum chloride was toxic in concentrations above 0.00005 molar. Added to Lake Erie water aluminum chloride hydrolyzed and produced an acid reaction. Concentrations above 0.0008 molar had a pH of 5 or less. A precipitate was also produced which was light to negligible in solutions with a pH of 5 or lower. A flocculent precipitate formed in 0.0004 molar and the pH was 7.5. As the concentration decreased the precipitate became lighter and the pH approached 8.2, that of Lake Erie water. The precipitate was present in the threshold and lower concentrations and may have been a factor influencing the toxicity threshold. Jones (1939) reported that the threespine stickleback did not survive in concentrations of aluminum nitrate greater than 0.0000026 molar in Aberystwyth tap water. He found that 0.5 p.p.m. aluminum (0.0000185 molar as aluminum nitrate) gave a pH of 5. He reported that this concentration of aluminum was toxic whereas a hydrochloric acid solution of the same pH in Aberystwyth tap water was not. The pH of his aluminum nitrate solution at the threshold was 6.2. Jones also said that he obtained similar results with potassium aluminum sulfate. Ellis (1937) found that 100 p.p.m. (0.00039 molar) aluminum potassium sulfate in hard water killed goldfish in 12 to 96 hours.

Cobalt Chloride.—The toxicity threshold of cobalt chloride was 0.000024 molar. This concentration is considerably lower than that presented by Anderson (1944). The increased exposure time for the present experiments accounts for the difference. Were the exposure time increased still further and the trend of the concentration-immobilization time curve continued unchanged, the threshold would decrease 10 times for each quadrupling of the exposure time. Ellis (1937) found that 10 p.p.m. (0.000077 molar) cobalt chloride in soft water was fatal to goldfish in 168 hours. Jones (1939) stated that the lethal concentration limit for the threespine stickleback was 0.000168 molar in Aberystwyth tap water.

Chromic Chloride.—The threshold of toxicity for chromic chloride was 0.000023 molar (Fig. 2). Chromic chloride hydrolyzes and produces an acid solution. In Lake Erie water 0.0003 molar solution had a pH of 5.6. Higher concentrations of chromic chloride reduced the pH still further.

In 0.000063 molar concentrations the pH was 8.0. In concentrations above 0.0003 molar the solutions were clear but below this value a gray precipitate formed until a concentration of 0.0000027 molar was reached below which no precipitate was discernable. The precipitate may, therefore, have played a part in immobilizing the daphnids, either through mechanical means or through a specific toxic action of the precipitate. Jones (1939) reported that 0.000023 molar was the threshold of toxicity to the threespine stickleback for a chromium sulfate in Aberystwyth tap water. This concentration of chromium (but in the form of the chloride) is the same that was the threshold for *Daphnia magna*.

Nickel Chloride.—The next most toxic chloride was nickel chloride. Its threshold of toxicity was 0.0000054 molar. In concentrations of 0.004 molar and higher, nickel chloride produced a precipitate in Lake Erie water, but at 0.0008 molar and less the solutions were clear. Ellis (1937) cited some results on *Fundulus heteroclitus*. They were killed by 8.1 p.p.m. (0.0000625 molar) nickel chloride in tap water but they survived 259.2 p.p.m. (0.002 molar) in salt water. Ellis also pointed out that 10 p.p.m. (0.000077 molar) in soft water killed goldfish in 200 to 210 hours. Jones (1939) reported that 0.0000134 molar nickel nitrate in Aberystwyth tap water was the threshold for the threespine stickleback.

Lead Chloride.—Lead chloride was somewhat more toxic than nickel chloride. Its threshold was 0.0000045 molar. Lead chloride hydrolyzed to produce a slightly acid solution in concentrations above 0.001 molar. At 0.005 molar the pH was 5.9 and at 0.001 molar the pH was 6.8. A precipitate formed in 0.005 molar solutions and settled out leaving the solutions clear. In 0.001 molar a precipitate formed but the solution remained turbid. In 0.00046 molar less precipitate formed yet the turbidity increased. In all lower concentrations both the precipitate and the turbidity decreased but were discernable in concentrations down to 0.0000012 molar which was below the threshold. The turbidity may have been a factor in immobilization of the *Daphnia* since it occurred in the threshold and lower concentrations. Naumann (1934d) found that 0.01 p.p.m. lead as lead chloride (0.000000048 molar) in each of several different waters killed *Daphnia magna* in 10 days. Naumann obtained the same results with 1.0 p.p.m. and 0.1 p.p.m. lead in the same waters. The fact that he obtained the same results with varying concentrations of lead and in different waters leads me to believe that some other factor was operating and consequently that Naumann's lethal limits are too low.

Ellis (1937) cited Carpenter as believing that 0.33 p.p.m. (0.0000016 molar) lead may be lethal to fresh-water fishes. Ellis listed the results of other investigators and pointed out that 10 p.p.m. (0.00003 molar) lead acetate in stream water killed yearling trout (species not stated) and 10 p.p.m. (0.00003 molar) lead nitrate in stream water killed trout in 2 hours and 15 minutes. In his own experiments Ellis found that 100 p.p.m. (0.0003 molar) lead nitrate in hard water was fatal to goldfish in 80 hours but that 10 p.p.m. (0.00003 molar) in hard water caused no apparent in-

jury in 96 hours. Jones (1939) reported that 0.00000048 molar lead in Aberystwyth tap water was the threshold for the threespine stickleback.

Zinc Chloride.—The threshold of toxicity to *Daphnia magna* for zinc chloride was 0.0000011 molar (Fig. 2). This value is much lower than that given by Anderson (1944) for zinc sulfate on the basis of a 16-hour exposure. The concentration-immobilization time curve for zinc sulfate in the earlier experiments coincides with the one for zinc chloride shown in Figure 2 except that the segment beyond 16 hours is lacking. Had the exposure time been longer in the earlier experiments the curves presumably would have been identical and the threshold for the sulfate would have been the same as for the chloride.

When zinc chloride was added to Lake Erie water a precipitate formed when the concentrations were higher than 0.00032 molar. In 0.000064 molar and less no precipitate was discernable. It does not seem probable that the precipitation products entered into the toxicity of zinc at the threshold concentration.

Hutchinson (1933) reported that 0.00001 molar zinc in (pond?) water killed both *Daphnia magna* and *Daphnia pulex* in less than 5 days and *Ceriodaphnia reticulata* in less than 4 days. Fowler (1931) found that 0.001 molar zinc nitrate in well water killed *Daphnia longispina* in 15 hours. According to Naumann (1934c) 0.01 p.p.m. zinc as zinc sulfate (0.000000153 molar) killed *Daphnia magna* in hard water and that some *Daphnia magna* survived in soft water with 0.1 p.p.m. zinc as zinc sulfate (0.00000153 molar). Ellis (1937) noted that 100 p.p.m. (0.00062 molar) zinc sulfate in hard water killed many goldfish in 5 days. Jones (1939) reported that 0.0000046 molar zinc nitrate in Aberystwyth tap water appeared to be the threshold for the threespine stickleback. Fish seem to be more resistant to zinc than daphnids do.

Cupric Chloride and Cupric Ammonium Chloride.—Cupric chloride was toxic to *Daphnia magna* in all concentrations above 0.0000002 molar (Fig. 2). Cupric ammonium chloride was toxic in all concentrations above 0.00000016 molar (Table 1). The concentration-immobilization time curves are very nearly identical. Both cupric chloride and cupric ammonium chloride yielded precipitates with Lake Erie water when they were in higher concentrations than 0.000064 molar. Solutions of both salts in Lake Erie water had a pH of 6.1 or less in concentrations of 0.0016 molar or higher.

The threshold concentration for cupric chloride given by Anderson (1944) was higher since it was estimated on the basis of an exposure period of 16 hours. For the range of time covered, the curve for cupric sulfate shown by Anderson (1944) is very nearly the same as that given for cupric chloride in Figure 2 in the present paper. According to Naumann (1934b) 0.01 p.p.m. copper as cupric sulfate (0.00000015 molar) in hard water and 0.02 p.p.m. copper (0.0000003 molar) in oligohumus, soft water and in water from Straken Lake (mesohumus) killed *Daphnia magna.* In water from Frejen Lake (polyhumus) .02 p.p.m. copper killed

the larger but not the smaller *Daphnia magna*. Jones (1939) reported that the threespine stickleback did not survive in concentrations of cupric sulfate above 0.000000236 molar in Aberystwyth tap water. Ellis (1937) carried out a large series of experiments on cupric sulfate with goldfish as the test animals. He reported that they survived 1 p.p.m. (0.0000063 molar) cupric sulfate in hard water for 3 days and longer.

Silver Nitrate.—Because of the extremely low solubility of silver chloride, silver nitrate was used to represent silver salts. *Daphnia magna* did not survive in silver nitrate solutions above 0.00000003 molar (Figs. 1 and 2). In solutions 0.004 molar and higher a precipitate was produced. From 0.000032 molar to 0.0008 molar the solutions of silver nitrate in Lake Erie water were turbid but below 0.0000064 molar they were clear. The concentration-immobilization time curve for silver nitrate was different from those of all the other salts used in that the vertical asymptote was reached between 1 and 2 hours. This fact indicates that the silver nitrate acted within 2 hours or not at all. Jones (1939) found the silver nitrate threshold for the threespine stickleback to be 0.000000028 molar in Aberystwyth tap water, approximately the same as that found for *Daphnia magna* in Lake Erie water.

Mercuric Chloride.—Mercuric chloride proved to be slightly more toxic than silver nitrate. Its threshold was 0.000000022 molar (Table 1 and Fig. 2). Many investigations have been carried out on mercuric chloride in which relatively high concentrations killed in a short time. Apparently few investigators have concerned themselves with the minimum lethal concentrations. Jones (1939) reported that the threespine stickleback was killed by all concentrations above 0.00000004 molar in Aberystwyth tap water.

Cadmium Chloride.—The most toxic salt employed in these experiments was cadium chloride. The threshold was 0.000000014 molar (Table 1 and Fig. 2). In solutions made up to 0.0000128 molar and higher in Lake Erie water a precipitate formed. Jones (1939) reported that the threshold of toxicity to the threespine stickleback was 0.00000178 molar for cadmium nitrate in Aberystwyth tap water which is much greater than for *Daphnia magna*.

Comments on the Conduct, Interpretation, and Practical Application of Toxicity Experiments

In toxicity experiments in which *Daphnia* and other arthropods are employed it is important to plan exposure periods of long enough duration to insure that all the experimental animals will have had an opportunity to reach the molting stage. That the molting period is a critical one in the life of animals such as *Daphnia* is substantiated by the marked inflections in the concentration-immobilization time curves for many compounds at the time when molting was expected. Several explanations may be advanced for their greater susceptibility at molting. One is that immediately

after the old body covering is shed the new covering is soft and more permeable than the old, thereby permitting substances to enter the body at a greater rate than before molting. Another is that at their first molt *Daphnia magna* increase in length as much as 26 percent and sometimes more. Since they retain approximately the same body proportions after molting as they had before, the volume of the animals is doubled after molting (Anderson, 1932). As the animals increase in size immediately after molting the various substances in the environment enter the animals at a greater rate than they did before molting. A third explanation is that some phase of the molting process may be inhibited so that molting is prevented. Still another explanation is that the development of the new integument is abnormal. After molting the abnormal integument would interfere with normal functions and death would follow. Whatever the reasons are for the death of daphnids at molting, one might expect that other arthropods would react similarly under comparable conditions.

In determining thresholds of toxicity to many arthropods, only immature individuals can be used as test animals if the exposure period is to include a molting stage. The copepods, for instance, cease to molt on becoming mature and, therefore, thresholds determined by the use of mature individuals are likely to be higher than those determined through the use of immature animals and would be of limited value in pollution-abatement studies.

The main body of this paper gives the apparent toxicity thresholds for *Daphnia magna* as determined in the present experiments together with the results of other investigators on other animals, especially fish. In general it may be said that the *Daphnia* and other Crustacea are more susceptible to toxic substances than fish are. The thresholds for many metal salts vary with the nature of the diluent waters. The thresholds for some salts are higher in hard waters than in soft waters but for other salts the opposite is true. Since the diluent used in the present experiments was Lake Erie water which is considered as a semi-hard water (for an analysis see Anderson, 1946), a repetition of my experiments with other natural waters as diluents may not yield the same results as those presented here but they probably will not often be far different.

Many explanations have been offered for the toxicity of the various metals. Good correlations have been shown between the toxicity of a metal and its electrolytic solution pressure (Jones, 1939). Better correlations might be had between the toxicity and the frequency in which a metal occurs in living matter. In either correlation notable exceptions are to be found. The mode of action of a substance is very likely to vary with its concentration. In one concentration a substance may kill because of the osmotic pressure it exerts. At an intermediate concentration it could very well be lethal because of the acidity produced. In the region of the threshold concentration a metal may prove to have a more or less specific action. Cupric chloride may act in each of these ways, depending on its concentration. Adequate explanations of the mode of action in the region

of the threshold concentration await further fundamental work on individual metals and on the nature of the reactions of living matter to them.

It is not my intention that the thresholds presented here should be set up as standards for admitting metal compounds into natural waters. It must be borne in mind that the values given are for immobilization of 50 percent of the animals in 64 hours at 25° C. Many vital processes may be impaired at lower concentrations without producing immobilization or death. One may expect that the results of further investigations will show that the permissible concentrations should be lower to avoid injury to aquatic organisms. More research will be necessary to establish safe levels at which substances may be admitted to streams and lakes. Certainly, since the diluent employed in these experiments was Lake Erie water, the disposal of wastes in Lake Erie should be so modified where necessary that the concentration of any constituent will not exceed the threshold for that substance as given here. It seems unlikely that the ultimate standards will exceed the threshold concentrations for *Daphnia*.

Acknowledgement

The experimental work was carried out during the summer of 1945 at the Franz Theodore Stone Laboratory, The Ohio State University, Put-in-Bay, Ohio. I wish to express my appreciation to the members of the staff of the Franz Theodore Stone Laboratory for their cooperation and especially to the director, Dr. T. H. Langlois, for his encouragement. Thanks are also due to West Virginia University, as well as The Ohio State University, for furnishing that essential component for research—time.

Literature Cited

Anderson, B. G.

1932. The number of pre-adult instars, growth, and variation in *Daphnia magna*. Biol. Bull., Vol. 63, pp. 81–98.

1944. The toxicity thresholds of various substances found in industrial wastes as determined by the use of *Daphnia magna*. Sewage Works Jour., Vol. 16, pp. 1,156–1,165.

1946. The toxicity thresholds of various sodium salts determined by the use of *Daphnia magna*. Sewage Works Jour., Vol. 18, pp. 82–87.

Anderson, B. G., D. C. Chandler, T. F. Andrews, and W. J. Jahoda

1948. The evaluation of aquatic invertebrates as assay organisms for the determination of the toxicity of industrial wastes. Final Report on a project sponsored by the American Petroleum Institute and carried out at the Franz Theodore Stone Laboratory, The Ohio State University, Put-in-Bay, Ohio, 51 pp.

Anderson, B. G., and J. C. Jenkins

1942. A time study of events in the life span of *Daphnia magna*. Biol. Bull., Vol. 83, pp. 260–272.

Banta, A. M.

1939. Studies on the physiology, genetics, and evolution of some Cladocera. Carnegie Inst. Wash., Publ. No. 513, 285 pp.

Baylor, E. R.

1942. Cardiac pharmacology of the cladoceran, *Daphnia*. Biol. Bull., Vol. 83, pp. 165–172.

Chipman, W. A.
1934. The role of pH in determining the toxicity of ammonium compounds. Thesis, Universty of Missouri. University Microfilms, Ann Arbor, 155 pp.

Edmister, J. O., and J. W. Gray
1948. The toxicity thresholds for three chlorides and three acids to the fry of whitefish (*Coregonus clupeaformis*) and yellow pickerel (*Stizostedion v. vitreum*). Prog. Fish-Culturist, Vol. 10, pp. 105–106.

Ellis, M. M.
1937. Detection and measurement of stream pollution. Bull. U.S. Bur. Fish., Vol. 48, pp. 363–437.

Fowler, J. R.
1931. The relations of numbers of animals to survival in toxic concentrations of electrolytes. Physiol. Zool., Vol. 4, pp. 214–245.

Hutchinson, G. E.
1933. Experimental studies in ecology. I. The magnesium tolerance of Daphniidae and its ecological significance. Int. Rev. d. ges. Hydrobiol. u. Hydrog., Bd. 28, S. 90–108.

Jones, J. R. E.
1939. The relation between the electrolytic solution pressures of the metals and their toxicity to the stickleback (*Gasterosteus aculeatus* L.) Jour. Exp. Biol., Vol. 16, pp. 425–437.
1940. A further study of the relation between toxicity and solution pressure, with *Polycelis nigra* as test animal. Jour. Exp. Biol., Vol. 17, pp. 408–415.

Meek, A.
1916. The migration of fish. Edward Arnold, London, 427 pp.

Naumann, E.
1934a. Über die Beeinflussung von *Daphnia magna* durch einige Salze und Salzmischungen. K. fysiogr. Sällsk. Lund Förh., Bd. 4, S. 11–22.
1934b. Über die Toxizität des Kupfersulfats für *Daphnia magna*. K. fysiogr. Sällsk. Lung Förh., Bd. 4, S. 41–49.
1934c. Über die Toxizität des Zinksulfats für *Daphnia magna*. K. fysiogr. Sällsk. Lund Förh., Bd. 4, S. 123–128.
1934d. Über die Toxizität des Bleichloride für *Daphnia magna*. K. fysiogr. Sällsk. Lund Förh., Bd. 4, S. 129–134.

Ramult, M.
1925. Development and resisting power of Cladocera embryos in the solutions of certain inorganic salts. Bull. l'Acad. Polon. Sci., Série B, 1925, pp. 135–194.

Warren, E.
1900. On the reaction of *Daphnia magna* (Straus) to certain changes in its environment. Quart. Jour. Micr. Sci., Vol. 43, pp. 199–224.

A NEW CELLULOID OPERCULAR TAG

R. A. McKenzie

Fisheries Research Board of Canada
Chatham, New Brunswick

Abstract

A new celluloid opercular tag developed for smelt (*Osmerus mordax*) investigations has given promising results. From 11,000 smelt tagged, almost 6,800 or 59 percent were returned during the winter fishery. Tank experiments with smelt and Eastern brook trout (*Salvelinus fontinalis*) indicate some tagging mortality and show that tags are soon lost under tank conditions in summer.

Introduction

When an attempt was planned in 1943 to determine the proportion of smelt taken by the fishery in the Miramichi Estuary in northeastern New Brunswick, it was realized that the tag used for this purpose would have to be conspicuous and still not too heavy to be carried by these relatively small fish. As smelt are caught through the ice, often in severe weather, and are handled in large numbers frozen and mixed with snow, an inconspicuous tag would usually escape notice. The celluloid opercular tag which was developed and used is described here.

The tag was developed in experiments at the Atlantic Biological Station, St. Andrews, New Brunswick, in the early part of 1943 by Mr. A. E. Calder, who selected it from among a number of alternative marks which were tried on captive smelt in salt-water tanks.

Description of the Tag

The tags are made of scarlet celluloid (Red Xylonite, 0.010-inch thickness) by cutting pieces in a form such as shown in Figure 1A by means of steel dies. These "blanks" are first placed in almost boiling water for 30 seconds or more. Then the tail-piece is seized with forceps near the point at which it joins the shield and the latter is bent back tightly against the tail with the fingers and held in that position with another pair of forceps while the tag is cooled in cold water. The resulting tag is sketched in Figure 1 (B and C). For ease of application the tail is made long enough to extend a little way past the shield.

Distinctive marks can be made on shields of various shapes with waterproof ink, scissors, or punches before the tag is bent. In this way groups of fish marked at various times or places can be distinguished.

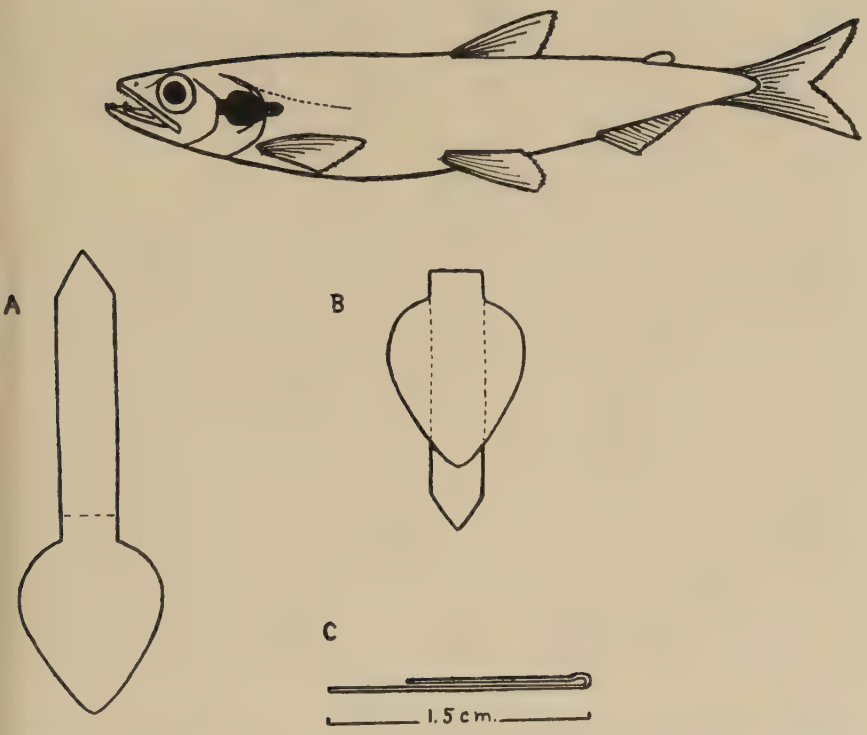

FIGURE 1.—The opercular tag attached to a smelt. Below; A. the tag as cut from celluloid sheets; B. top view after bending; C. side view after bending.

APPLICATION OF THE TAG

In putting these tags on smelt the shield is held firmly in a pair of square-nosed forceps. The free tail part is inserted between the operculum and pre-operculum and turned backwards under the gill cover. Thus the conspicuous scarlet shield is outside and the tail inside protruding just past the gill opening. The two arms, which were pressed tightly together in the process of making the tag, exert a slight pressure on the gill cover. When a second person is available to put the tags on the forceps, six smelt per minute can be tagged easily.

USE OF THE TAG IN THE WINTER SMELT FISHERY

From 1943 to 1947 just over 11,000 of these tags were used on Miramichi smelt during or just prior to the fishery in December, January, and February. Of this total almost 6,800 or 59 percent were returned. The

recaptures from the individual taggings ranged from as low as 30 percent to as high as 86 percent depending on the intensity of the fishery in the tagging district. Almost all of the recaptures were made within the period of a season's fishery, *i.e.*, 2 to 3 months. Only 17 or 0.1 percent were taken as much as a year after tagging.

Limitations of the Tag

Two tests have been made in tanks which indicate that the tags are soon lost under summer conditions and that some mortality is caused by the tagging operation. Smelt held in salt-water tanks at St. Andrews, New Brunswick, from May 18 to August 24, 1943, showed a mortality of about 15 percent among those tagged as compared with only about 5 percent among controls. The tags were retained well until about the beginning of August (10 weeks) but by August 24 all the tags had been lost. Fifty-one tagged yearling brook trout held in a hatchery retaining pond at Saint John, New Brunswick, from July 9 to August 16, 1943, had a mortality of 36 percent as compared with 7 percent among controls. Only two of the survivors retained their tags to the end of the experiment. In both of these experiments the tags were lost as the result of festering, which removed a part of the gill cover from the point at which the tag was inserted to the posterior margin. There was no indication in the experiments that any of the tags had been lost by any other manner.

These experiments indicate that tags of this type are not suitable for long-term experiments. The proportions recovered in the winter smelt fishery were so high, however, that it appears that the tag has considerable value in short-term estimates of fishing mortalities under favorable conditions.

SULFONAMIDE THERAPY OF FURUNCULOSIS IN BROWN TROUT

KENNETH G. FLAKAS

Wisconsin Conservation Department
Madison, Wisconsin

ABSTRACT

Studies were made, both in the field and in the laboratory, to determine the effectiveness of sulfonamides in the treatment of the disease furunculosis in the brown trout (*Salmo trutta*).

When sulfamerazine was fed at a level of 8 grams per 100 pounds of trout, the infected fish were not always rid of the bacterium which causes furunculosis.

In the laboratory it was found that when virulent cultures of *Bacterium salmonicida* were injected into brown trout on the first day of the sulfamerazine feeding, several of the trout developed active infections after the treatment was discontinued. When virulent cultures were injected into trout on the fourth day of the sulfamerazine feeding, several "carriers" of furunculosis developed. A combination of sulfamerazine and sulfaguanidine was apparently effective in ridding experimentally infected trout of the bacterium of furunculosis.

A bacteriological study was made of an outbreak of furunculosis which occurred in the brown trout fingerlings of a state hatchery. The epidemic was treated by the daily use of 8 grams of sulfamerazine per 100 pounds of trout. The sulfamerazine treatment produced a marked drop in the mortality rate of the fingerlings, but positive cultures were encountered in some treated fingerlings 8 days after the completion of the treatment. A secondary feeding of sulfamerazine at the 8-gram level was given to the hatchery trout in an effort to eliminate "holdovers" of the disease. Two positive cultures were obtained from live and apparently healthy brown trout after the secondary treatment, indicating that some of the treated hatchery trout were "carriers."

An outbreak of furunculosis, which occurred among the brood-stock brown trout of a state hatchery, was treated by the use of a combination of sulfamerazine and sulfaguanidine. The treatment produced a marked drop in the mortality rate. To date, the brown trout treated by this combination of sulfonamides have yielded negative bacteriological cultures.

INTRODUCTION

The eradication of the disease furunculosis from a trout hatchery has long been a problem confronting the trout culturist. Until recently, the only method of combating furunculosis in a hatchery was the disposal of the entire stock of infected trout. With the discovery of the effectiveness of sulfamerazine in the treatment of furunculosis (Gutsell, 1947), the trout culturist finally had a therapeutic means at his disposal that reduced the loss of trout in a most gratifying manner. It has been observed, however, that hatchery trout which have been treated for active furunculosis by the

use of sulfamerazine, are not always free of secondary, post-treatment attacks of the disease. The question immediately arises as to whether all trout treated with sulfamerazine are actually freed of the bacterium causing furunculosis. If the treatment is not totally effective, the trout culturist is then faced with the existence of "carriers" of the disease. Since a "carrier" state has been found to be of great importance in the spread of furunculosis among untreated trout (Mackie *et al.*, 1935), the possibility of the existence of such "carriers" after a sulfonamide treatment should not be ignored. It can be seen readily that anything short of the complete eradication of the bacteria of furunculosis from a group of infected trout can only tend to produce a "carrier" state with its attendant danger to the remaining healthy stock.

A series of experiments was instituted in order to determine the actual effectiveness of present methods of sulfonamide therapy in eliminating the causative agent of furunculosis from the trout body. The investigation involved two lines of research. The first phase consisted of a series of laboratory experiments designed to study the reaction of individual trout, which were treated with sulfonamides, to inoculations of the bacterium of furunculosis. The second phase consisted of a bacteriological study of a furunculosis outbreak in a state fish hatchery during which the trout were treated with sulfamerazine.

Laboratory Experiments on Infection and Treatment of Brown Trout

Experimental procedure.—Experiments were set up in the laboratory which would permit close observation of the effect of the administration of different sulfonamides on brown trout which were inoculated with the bacterium of furunculosis. Five lots of 2-year-old "normal" brown trout (three fish per lot) were placed in experimental tanks 14 feet long, 18 inches wide, and 15 inches deep. All of the trout used in the experimental series were placed in the tanks for a period of 1 week prior to the beginning of the experiment.

The brown trout in Series A and B were fed sulfamerazine (mixed with canned carp) over a 6-day period, at a daily level of 8 grams of drug per 100 pounds of trout.

The trout in Series C and D were fed a mixture of sulfamerazine and sulfaguanidine at a level of 5 grams of sulfamerazine plus 3 grams of sulfaguanidine per pound of food. Each group of three trout was fed one-quarter pound of the sulfonamide-food mixture daily over a 6-day period. The relatively high dosage level of sulfamerazine-sulfaguanidine combination used in Series C and D had been found in previous experimental work to be effective against the septicemic disease red sore which attacks fish and frog.

The brown trout of Series A and D were inoculated intramuscularly

with 0.05 milliliter of a young broth culture of *B. salmonicida* on the first day of the respective sulfonamide feedings. These inoculations were made in an effort to determine if a trout, inoculated with *B. salmonicida* before sulfonamides were present in the blood stream, could be rid of the pathogen by subsequent feedings of the sulfonamide drugs. Series A and D thus permitted a study of the effect of ingestion of sulfonamides by a brown trout which had an incipient infection at the start of the treatment. This type of experiment was considered important since an earlier study in this laboratory of the effect of sulfamerazine on subterminal or terminal furunculosis infections in trout indicated that even massive doses of sulfonamides, administered orally, might fail to check this disease.

Brown trout of Series B and C were inoculated intramuscularly with 0.05 milliliter of a young broth culture of *B. salmonicida* on the fourth day of the sulfonamide feeding, after a protective blood-sulfonamide level had been established. It had been found that a sulfamerazine level of 7 milligrams or more per 100 milliliters of blood was therapeutically effective in the treatment of active furunculosis in trout. Series B and C were set up, therefore, to determine whether *B. salmonicida* might not remain in a brown trout despite the existence of a protective blood sulfonamide level at the time of entrance of the pathogen into the trout body.

One control tank was set up, in which untreated 2-year-old brown trout were inoculated intramuscularly with *B. salmonicida*. The trout so inoculated developed typical furunculosis lesions and died 3 days after they were inoculated. Pure cultures of *B. salmonicida* were recovered from the heart blood, kidneys, and lesions of the control group.

All of the groups of brown trout were fed their respective sulfonamide dosages for 6 consecutive days, then given a 4-day period without treatment, and finally were fed sulfonamides for 4 consecutive days.

The secondary 4-day period of sulfonamide feedings was instituted when it became apparent that "carrier" trout were developing during the experiment. It was thought that perhaps the use of a secondary "booster" dosage might clear the carriers of the bacterium of furunculosis.

Samples of blood were taken from the experimental trout at regular intervals and cultured. The blood cultures were made in an effort to determine if the bacterium of furunculosis was present in the blood stream during and after the experimental feeding of sulfonamides. A record was kept also of the progressive appearance of any lesions that developed on the experimental fish.

Determinations were made of the blood-sulfonamide levels of the trout by means of a Goth sulfonamide kit. To obtain the heart blood for the sulfonamide determinations and for the blood cultures, a technique was used in which a hypodermic needle was inserted into the body of the trout at a point on the midline of the ventral surface immediately anterior to the pectoral fins.

At the close of these observations, the experimental brown trout were

all sacrificed and cultures were made in an effort to detect any latent infections. Aspirations of the trout kidneys were inoculated into tubes of fish-infusion broth.

Evaluation of the responses of the inoculated brown trout to treatment.— Details concerning the observations on the several experimental lots are given in the following paragraphs.

Series A. Inoculation of *B. salmonicida* on first day of feeding with sulfamerazine.

1. On the fourth day after inoculation, the brown trout had only a slight pin-point swelling at the site of inoculation in contrast to the marked lesions and fatal septicemias encountered in the control group.

2. Trout No. 1 (identified by fin clipping) exhibited only pin-point swellings at the site of the inoculation and failed to develop an active infection.

3. Trout No. 2 failed to rid itself of the bacteria inoculated, even after building up a good blood-sulfonamide level. This trout finally succumbed to the infection when the sulfonamide level dropped below 7 milligrams on the twelfth day of the experiment.

4. Trout No. 3 failed to build up a good protective blood-sulfonamide level at any time and was consequently overwhelmed by the infection.

Series B. Inoculated with *B. salmonicida* on the fourth day of feeding with sulfamerazine.

1. The brown trout in this series maintained a good, protective blood-sulfonamide level in the initial feeding of sulfonamide.

2.. None of the trout in Series B developed active lesions. Positive cultures were obtained, however, from the blood of two of the three trout in this series.

3. The positive blood cultures were not obtained until the blood sulfonamide dropped below the 7-milligram level. This reaction indicated that the bacterium was not destroyed but was only attenuated by the action of the sulfamerazine.

Series C. Inoculated with *B. salmonicida* on the fourth day of the sulfamerazine-sulfaguanidine feeding.

1. The brown trout in this series maintained good protective sulfonamide levels during the experiment.

2. The trout failed to yield positive blood cultures at any time during the experiment.

3. All of the fish in the series exhibited a slight swelling at the site of inoculation, which subsided completely by the end of the experiment.

Series D. Inoculated with *B. salmonicida* on the first day of the sulfamerazine-sulfaguanidine feeding.

1. Trout No. 3 failed to feed from the beginning of the experiment and consequently did not build up a protective blood-sulfonamide level.

2. Trout Nos. 1 and 2 fed normally and developed protective blood-sulfonamide levels. The trout failed to yield positive blood cultures during

the experiment. These fish exhibited only slight swellings at the sites of inoculation which later subsided completely.

At the close of the experiment, kidney aspirations were taken from all of the surviving trout. The aspirations from the trout of Series B were positive for *B. salmonicida,* where as those from Series A, C, and D were negative for this pathogen.

The results obtained from the laboratory experimental series revealed several apparently characteristic reactions (*in vivo*) of *B. salmonicida* to treatment with sulfonamides.

1. Only a small amount of sulfonamide need be ingested to inhibit the disease-producing action of *B salmonicida.* This fact is evidenced by a comparison of the pin-point lesions on the treated trout on the fourth day of the experiment with the marked lesions and fatal septicemia in the control group on the same day.

2. In Series A, in which sulfamerazine alone was fed, the reduction of the pathogenicity of *B. salmonicida* was only temporary. This fact is evidenced by the final outbreak of a fatal infection in Trout No. 2, when the blood-sulfonamide level fell below the protective range. The temporary attenuation was noted only in Series A, wherein the pathogen was inoculated on the first day of the feeding with sulfamerazine. It would appear that when *B. salmonicida* enters the body of a trout possessing a blood-sulfonamide level which is non-protective, this pathogen can remain in the body in a state of temporarily arrested virulence. The state of arrested virulence can continue to exist despite the subsequent establishment of a "protective" blood-sulfonamide level. Consequently an active infection could develop when the blood-sulfonamide level drops to a non-protective value. This type of attenuation is potentially as dangerous as the true "carrier" state, as it can retard the active infection until after the sulfamerazine treatment is completed.

3. In contrast to the reactions in Series A, the reactions in Series B show that when *B. salmonicida* enters the body of a brown trout possessing a protective blood-sulfonamide level, the pathogen can be retained in the host without producing an active infection. It was seen that an active infection did not develop even after the blood level had dropped below the protective range. It is believed that, experimentally, Series B produced a true carrier trout.

4. The sulfamerazine-sulfaguanidine mixture completely eradicated the pathogen *B. salmonicida,* from the trout in the experimental Series C and D.

5. The factor of variation in feeding rates among individual fish, especially those heavily infected at the time of treatment should be recognized. The variation in feeding rate would indicate that a certain percentage of treated trout will fail to build up a good blood-sulfonamide level and consequently be overwhelmed by the infection.

6. It must be remembered that the above-mentioned observations were made on a small number of trout and simply indicate the types of reactions which may be encountered. The number of brown trout in the experimental

series was purposely kept low so that the individual fish could be checked as to the blood-sulfonamide levels reached and the progress of the experimental infections. It will be seen that the reactions observed were encountered again in a later study of a furunculosis outbreak in a state hatchery.

Bacteriological Study of a Furunculosis Outbreak Among Brown Trout Fingerlings at the Wild Rose State Hatchery

Account of the outbreak and of the treatment.—Outbreaks of furunculosis have been frequent at the state trout hatchery located at Wild Rose, Wisconsin. Bacteriological cultures had been made from the trout in the Wild Rose Hatchery in January 1948 as a part of a check for "endemic" furunculosis among the state trout hatcheries. The check cultures were negative for *B. salmonicida* at all of the hatcheries studied. Later investigations of endemic furunculosis revealed that the number of carrier trout in a hatchery where furunculosis exists in an endemic form is so small as to make their detection by routine bacteriological examinations difficult.

The mortality rate of the brown trout fingerlings at the Wild Rose Hatchery began to increase markedly about July 20, 1948. Cultures, made of the dead fingerlings, were positive for *B. salmonicida*. The fingerling brown trout at Wild Rose were treated daily with sulfamerazine at a level of 8 grams per 100 pounds of trout for 7 consecutive days. The sulfamerazine produced a sharp, progressive drop in the mortality rate until it fell below the lower limits of the rate for previous months (see Fig. 1 and Table 1).

A bacteriological check was made of these fingerlings over a period of 2 months, including both the pre- and post-treatment time.

Reactions of the brown trout fingerlings to treatment.—Although the mortality rate dropped progressively from the first day of treatment, some of the dead fish that were examined during the treatment period exhibited typical lesions and yielded positive cultures of *B. salmonicida*. Obviously some of the trout were being overwhelmed by the infection despite the treatment with sulfamerazine. (Similar findings were encountered in the laboratory.)

Eight days after the completion of the 7-day feeding with sulfamerazine, four of the dead fingerlings were found to have furunculosis lesions which appeared active but not to the usual marked degree. These trout yielded positive cultures of *B. salmonicida*.

The above reaction might well be the same as that found in Series A of the laboratory experiments, where the brown trout developed active lesions after the sulfamerazine treatment was completed and the blood-sulfonamide level had dropped below the protective range.

At the time in the post treatment period that infected fish were detected, the mortality rate was below the usual "normal" level. Thus, a few diseased

fish might easily escape detection in a hatchery, not only because they are so few but also because they usually do not have marked lesions. The actual role the diseased "holdover" trout play in furunculosis will have to be studied more closely before we can judge to what extent they are responsible for post-treatment outbreaks.

When actively infected brown trout were found 8 days after treatment

TABLE 1.—*Record of daily mortality of brown trout fingerlings at the Wild Rose Hatchery, Wisconsin, May 16 to August 25, 1948*

Asterisks indicate days on which sulfamerazine was fed (daily dosage rate of 8 grams per 100 pounds of fish)]

Date	Mortality (number of fish)	Date	Mortality (number of fish)	Date	Mortality (number of fish)	Date	Mortality (number of fish)
May 16	73	June 6	187	July 16	280	August 6*	368
do. 17	34	do. 7	150	do. 17	310	do. 7*	342
do. 18	91	do. 8	152	do. 18	320	do. 8*	375
do. 19	108	do. 9	152	do. 19	342	do. 9*	310
do. 20	96	do. 10	152	do. 20	412	do. [1]10*	225
do. 21	135	do. 11	150	do. 21	370	do. 11*	170
do. 22	120	do. 12	130	do. 22	375	do. 12	125
do. 23	141	do. 13	130	do. 23	521	do. 13	93
do. 24	131	do. 14	143	do. 24	610	do. 14	60
do. 25	156	do. 15	235	do. 25	597	do. 15	67
do. 26	170	do. 16	246	do. 26	612	do. 16	41
do. 27	244	do. 17	238	do. 27	480	do. 17	43
do. 28	256	do. 18	218	do. 28	463	do. 18	37
do. 29	242	do. 19	220	do. 29	478	do. [1]19*	39
do. 30	200	do. 20	137	do. 30	415	do. 20*	35
do. 31	210	do. 21	132	do. 31	382	do. 21*	36
June 1	146	do. 22	141	August 1	425	do. 22*	32
do. 2	141	do. 23	144	do. 2	462	do. 23*	38
do. 3	161	do. 24	162	do. 3	523	do. 24	36
do. 4	250	do. 25	155	do. [1]4	420	do. [2]25	56
do. 5	210	.....	.....	do. 5*	432	.....	.....

[1] At least one culture positive for furunculosis
[2] Cultures negative

with sulfamerazine, a secondary "booster" treatment was instituted. The "booster" treatment consisted of feeding sulfamerazine at a dosage rate of 8 grams of drug per 100 pounds of trout for 5 consecutive days. It was hoped that this secondary treatment would rid any holdovers of the bacterium of furunculosis.

In the period during and immediately after the secondary treatment, no active lesions were to be found on any of the fingerlings examined. Bacteriological cultures, made of the live and dead fingerlings on September 3 and September 29 of the post-treatment period, yielded one positive culture on each date from live fish but none from dead fingerlings. The live fish that yielded the positive cultures are the true carriers that keep the pathogenic bacteria alive in a hatchery. Similar carriers were encountered in the laboratory experimental Series B.

The treated brown trout at Wild Rose remained free of active furunculosis until May 1949 when the brown trout yearlings suffered a sharp increase of mortality which was found to be caused by infection with

B. salmonicida. The carrier trout known to be existent among the yearlings were in all probability the primary source of infection in this epidemic. Various adverse factors, such as overcrowding or an increase in water temperature, might well initiate an active infection in the carrier trout.

Treatment and Bacteriological Study of a Furunculosis Outbreak in Spawning Brown Trout at a State Hatchery

Account of the outbreak and of the treatment.—The mortality rate of the brown trout in the brood stock of the state hatchery at Wild Rose, Wisconsin, began to show a sharp increase during the spawning period of November 1948. Previous bacteriological examinations of these fish had failed to

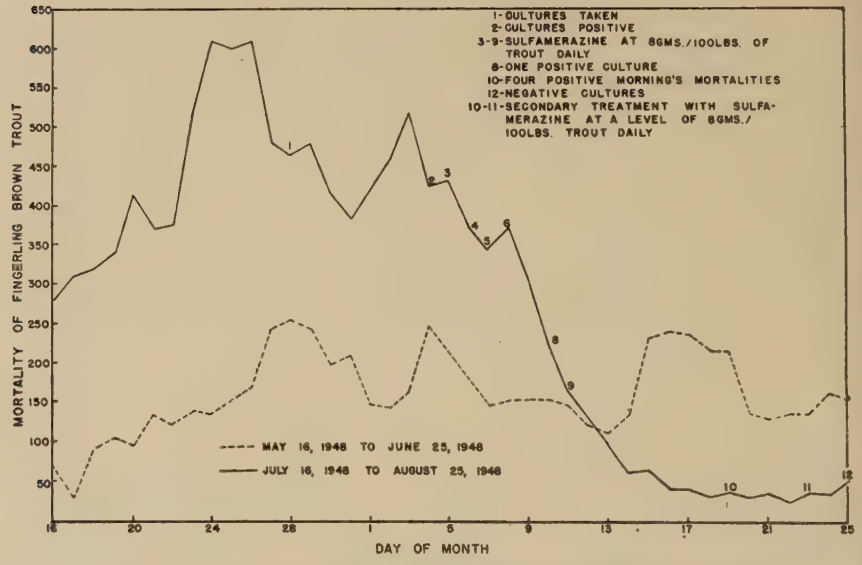

Figure 1.—Mortality of brown trout fingerlings at the Wild Rose Hatchery, Wisconsin.

reveal the presence of any pathogens. Dead specimens and the fish which appeared listless in the raceways, exhibited no external lesions. The only pathological condition in the affected trout was the markedly hemorrhagic state of the intestine along its entire length. Cultures made from the kidneys and intestines were positive for *B. salmonicida.* Again we had an outbreak of furunculosis in a group of fish from which negative cultures had been obtained in previous bacteriological examinations. The negative bacteriological findings would indicate again that the carriers among a large number of trout are so few as to make their detection difficult. The carrier fish that must have been present, doubtless were so weakened by the re-

peated handling plus the attendant rigors of spawning that they developed an active infection.

The effect of such an adverse factor as constant rehandling could readily be seen in the increase of mortality among the brood-stock fish. Several groups of these fish were handled only once in the spawning operation, but other lots were handled several and some groups many times. As each group of brood-stock fish was handled for the last time, it was placed in a raceway. It was noticed, on examination of the mortality records, that the death rate increased in proportion to the number of times the trout were handled.

That the incidence of disease was widespread was proven by the recovery of positive cultures from all groups of the brood-stock. The increase of the mortality was not, therefore, due to one single factor but rather to a combination of factors such as (1) weakened spawning trout, (2) constant handling of fish, and (3) presence of disease in spawning trout.

Our first hatchery test of the effectiveness of the treatment of furunculosis with a combination of sulfamerazine and sulfaguanidine was made on the infected brown trout of the Wild Rose Hatchery brood-stock. Several dosage levels of this sulfonamide combination were first checked experimentally on groups of "normal" 2-year-old and fingerling brown trout from the Nevin State Hatchery in Madison, Wisconsin. The different dosages were tested to determine the blood-sulfonamide levels they produced and to eliminate the possibility of using toxic dosages. Although higher levels were found to be non-toxic to normal brown trout, it was decided to treat the adult brown trout at the Wild Rose Hatchery with the following sulfonamide dosages. For the first 3 days the daily dosage rate was 12 grams of sulfamerazine plus 6 grams of sulfaguanidine per 100 pounds of fish. For 7 consecutive days, beginning with the fourth day of the treatment, the dosage rate was 6 grams of sulfamerazine plus 4 grams of sulfaguanidine per 100 pounds of trout.

Reactions of the adult brown trout to treatment.—Determinations of blood-sulfonamide levels were made during the course of the treatment with the following results: On the morning of the fourth treatment day (before the daily feeding) the levels averaged 11 milligrams per 100 milliliters of blood; on the morning of the seventh treatment day the levels averaged 9 milligrams per 100 milliliters of blood; and on the morning of the tenth and last treatment day (the final feeding of sulfonamide) the levels averaged 8 milligrams per 100 milliliters of blood.

In this series, a small percentage of the brown trout, which were badly fungused from repeated handling, failed to feed at all and succumbed to the disease.

Cultures made from kidneys of the treated adult brown trout on the final day of treatment, were all negative for *B. salmonicida.*

The sulfonamide treatment of the adult trout at the Wild Rose Hatchery produced a reduction of the number of mortalities to the "normal" level for these fish.

Recommendations on Procedure for the Treatment of Furunculosis

Although the accepted method of treating furunculosis by the use of sulfamerazine undoubtedly is of great value in reducing the destructiveness of this disease, it is not a totally effective means of ridding a trout hatchery of the pathogen. Studies in the laboratory and in the hatchery demonstrated the existence of carriers among groups of brown trout, despite treatment with sulfamerazine. The error of regarding the sulfamerazine treatment as a means for a permanent cure, should be avoided and the possibility of the existence of potentially dangerous carrier trout in a group of treated fish should be kept in mind at all times.

The prolonged feeding of sulfamerazine in the treatment of active furunculosis and the indiscriminate use of this drug as a purely prophylactic measure should be recognized as dangerous. Such practices might well bring about the production of "sulfa-resistant" strains of *B. salmonicida*.

The evidence suggests that if a carrier trout develops during the course of a treatment with sulfamerazine, it will continue to be a carrier despite prolonged treatment.

A certain percentage of the brown trout under treatment with sulfonamides either will not feed or will feed at a low rate because of an overwhelming infection. These fish will succumb to the infection in the period during and immediately following the treatment. All dead and seriously ailing fish, therefore, must be removed daily from the tanks and raceways, to prevent post-treatment spread of the disease.

A constant dosage level of 8 grams of sulfamerazine per 100 pounds of trout possibly may be less than totally effective in combating furunculosis. This dosage builds up the blood-sulfonamide level slowly and thus allows a certain number of the treated trout either to develop an overwhelming infection or to become carriers, depending on the amount of sulfamerazine ingested.

An effective procedure for the treatment of furunculosis with sulfonamides should:

1. Build up a protective blood-sulfonamide level rapidly by the use of high initial dosages, thus increasing the number of effective treatment days (in which the blood level is 7 milligrams or over).

2. Maintain the initial high blood levels by the use of lower, secondary dosages and shorten the total treatment time to avoid the possibility of the development of sulfa-resistant strains of bacteria.

3. Make use of an intestinal-specific sulfonamide, such as sulfaguanidine, in conjunction with the systemic-specific sulfamerazine. The intestinal tract of the trout carries *B. salmonicida* during active infection with furunculosis, thus affording a good source of infective matter, by which the disease may be spread. Whereas sulfamerazine is absorbed into the blood stream, sulfaguanidine, for the most part, exerts its bactericidal action in the intestinal tract.

It was on the basis of the above criteria that the combination of sulfamerazine and sulfaguanidine was employed for the treatment of the infected brown trout of the brood stock at the Wild Rose Hatchery. This method of treatment may possibly be rendered more efficient by increasing the number of treatment days at high dosages or by increasing the total treatment period to 2 weeks. The relative efficiency of such modifications will have to be checked thoroughly before they can be recommended.

Acknowledgements

Acknowledgment of assistance and cooperation is made to personnel of the Nevin and Wild Rose hatcheries. The research was under the direction of D. John O' Donnell, Chief Biologist, who gave encouragement and also critically read the manuscript. The author also wishes to thank Professor William B. Sarles, head of the Agricultural Bacteriology Department, University of Wisconsin, for reading the manuscript and offering certain critical suggestions for its improvement.

Literature Cited

Gutsell, James S.
1947. The value of certain drugs, especially sulfa drugs, in the treatment of furunculosis in brook trout (*Salvelinus fontinalis*). Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 186–199.

Mackie, T. J., Joseph Arkwright, T. E. Pryce-Tannatt, J. C. Mottram, W. D. Johnson, and W. J. Menzies
1935. Final report of furunculosis committee, H. M. Stationary Office, Edinburgh, pp. 15–27.

THE REINTRODUCTION OF ATLANTIC SALMON INTO TRIBUTARY STREAMS OF LAKE ONTARIO

HUGH R. MCCRIMMON

Ontario Department of Lands and Forests
Toronto, Ontario

ABSTRACT

Experimental plantings of Atlantic salmon (*Salmo salar*) fry were made in Duffin Creek, Ontario County, each year from 1944 to 1948. From 1945 to 1947 a large part of the creek was planted uniformly at a density of one fry per yard, regardless of local stream conditions. Each of these uniform plantings was followed by a study of the survival and distribution of the salmon during life in the creek. Populations were estimated by the use of a one-man hand seine. Each of the three uniform plantings resulted in the same pattern of survival over the stream system and showed the comparative suitability of various stream types for rearing salmon. Unsedimented gravelly riffles were found to be necessary for a high survival of newly planted fry. Subsequent survival to the smolt stage in areas not characterized by lethal summer temperatures was largely dependent on suitable habitats to accommodate the fish as they become larger. Capture of smolts during the spring of 1948 showed that at least 2 percent of the fry planted in 1946 reached Lake Ontario in 1948. From the study of the survival of salmon it must be concluded that a number of sections of Duffin Creek are suitable for the rearing of salmon to the smolt stage. The fate of the salmon reaching Lake Ontario has yet to be determined.

Since 1944 the Ontario Department of Lands and Forests has been carrying out an experiment to determine whether or not Atlantic salmon can be reintroduced into the tributary streams of Lake Ontario.

Before the experiment itself is described, a brief history of the salmon in Lake Ontario waters will be given. In colonial times Atlantic salmon were abundant in Lake Ontario and ascended many of the tributary streams where they spawned each autumn. Although no records of the salmon catches are available, it seems that the number of fish declined steadily through the middle of the last century until a low ebb was reached, apparently in the 1860's. This serious decrease led to the development of the first Dominion Fish Hatchery on Wilmot Creek, 40 miles east of Toronto, in 1866. At this time Wilmot, who was in charge of the hatchery, stated that it was difficult to find a sufficient number of adult fish for spawning purposes.

The results from the establishment of the hatchery and the stocking of a number of streams with salmon were most encouraging as salmon reappeared in many of the streams on the Canadian side of Lake Ontario. In 1879, however, the salmon runs were small and in the years following

there was a further decline until in 1883 the hatchery was able to obtain only 84,000 eggs as compared with 1,500,000 in 1876. This scarcity of eggs resulted in the abandonment of attempts to restore salmon to Lake Ontario waters.[1]

The presence of salmon in various streams was reported for a number of years but gradually the number decreased until the last salmon to be recorded in a stream was observed in Wilmot Creek in 1896. Similar records of the disappearance of salmon are found for the American side of Lake Ontario. The last record there appears to be that of a 12-pound fish captured in the Oswego River in 1890. The last recorded salmon in the lake itself was a 7-pound fish netted off Scarborough Beach near Toronto in April 1898.

Although it is commonly believed that Lake Ontario salmon migrated to the sea, the limited information available indicates that the salmon never left Lake Ontario but spent their entire life in the lake and its tributary streams. Many opinions have been expressed as to the possible causes for the disappearance of salmon. Included among the causes ascribed are overfishing, particularly by illegal methods, construction of dams preventing ascent of the salmon to spawning beds, sedimentation of spawning beds, and pollution.

It is with this historical background that the present experiment was undertaken to determine whether streams flowing into Lake Ontario are now capable of supporting young Atlantic salmon to the smolt stage, and further, what type of streams give the best production. The stream chosen for the experiment was Duffin Creek which flows into Lake Ontario about 30 miles east of Toronto. This creek was one of the better salmon streams in colonial days and one of the last streams to support salmon in any numbers. It was chosen primarily for the variety of conditions that it offered and for its accessibility. The gradient of the stream bed is somewhat steeper than those of the neighboring streams, consequently the degree of silting is less than is common in the lower reaches of streams of southern Ontario. Duffin Creek, which drains approximately 150 square miles of agricultural land, consists of two main branches, each some 20 miles in length, which converge about 4 miles from Lake Ontario. Each branch with its tributaries presents a wide range of stream types from the cool, clear, source waters to the warm, sedimented, lower waters.

The general plan of the experiment has remained essentially the same each year. In June of 1944, 1945, 1946, and 1947, approximately 40,000 salmon fry at the stage of the first taking of food were planted over the stream system at a rate of one per linear yard. The eggs, of Miramichi River stock, were obtained through the courtesy of the Dominion Department of Fisheries and hatched at a provincial hatchery on Lake Ontario. At planting time, the fry were transported from the hatchery by truck in ice-cooled containers and placed in retainer cages in the stream. From

[1] For an account of the propagation of Atlantic salmon in these early years, consult the Annual Reports of the Canadian Department of Marine and Fisheries, 1869–1885.

these cages the immediately adjacent section of stream was planted. About 10,000 fry could be planted by this method each day. In all, 40,000 fry were planted each year. The same procedure was repeated for a number of years to establish soundly the comparative survival of the planted fish under the various conditions.

Following each year's planting, a study of the effect of stream conditions on the young salmon was carried out. In order that a comparison could be made of the numbers of salmon existing in each stream area, it was necessary to adopt a standard method for population assessment. A small hand seine was found experimentally to give reasonably satisfactory results in capturing about one third of the salmon present in the section fished. The efficiency of this method depended somewhat on local stream conditions. Larger seines, trap nets, and other conventional methods took salmon readily but the results could not be used satisfactorily for the comparison of populations over the stream system.

Determinations of survival and distribution of the introduced salmon showed the comparative suitability of the different stream types for rearing salmon to the smolt stage of descent to the lake. In each of the years in which 40,000 salmon have been planted (1944 to 1947) essentially the same picture of survival has developed. High survival has been limited to certain waters. In others the young salmon disappeared completely. The survival of young-of-the-year salmon in October in the different stream areas ranged from nil to about 60 percent of the number planted. Survivals of 20 percent or more are common in the better salmon streams.

Of the 40,000 salmon fry planted in each of the years, 1945, 1946, and 1947, the numbers that survived until October of the same year were estimated at 4,500, 4,100, and 5,000, respectively. Thus the percentage survival of young-of-the-year salmon has run between 10 to 14 percent for the part of the stream system planted, including the areas in which no salmon survived.

A study of the yearling Atlantic salmon from the plantings showed that between 70 and 80 percent of the parr in the stream in the fall of the first year were still present in October of the second year. Or to express it differently, between 7 and 9 percent of the 40,000 fry stocked each year were still in the stream 15 months after planting. The greatest loss took place immediately or shortly after planting.

It should perhaps be noted that the largest numbers of yearling salmon do not necessarily occur in quite the same location in which the greatest concentrations of young-of-the-year were found the previous year. This discrepancy may be explained in part by a movement of the larger fish to waters offering more suitable habitats for them.

Age determinations of the salmon show that very few remain in the stream for more than 2 years.

The similarity of results following each of the four identical plantings has shown certain stream types to be more suitable for salmon production than others. Most obvious is the fact that high survival has been generally

limited to the intermediate waters below the cool source streams where brook trout abound, and above the lower waters where high temperature and much silt seem to bring about the total disappearance of salmon.

The failure to recover any salmon from the lower part of the stream system was caused by lethal summer temperatures. Where temperatures were not a limiting factor, the amount of protective cover was of primary importance. The amount of protective cover, particularly for the fry when first planted, was generally inversely correlated with the degree of bottom sedimentation. Heavy predation on the salmon fry by certain fishes was observed. These predators included the Eastern brook trout, *Salvelinus fontinalis,* the creek chub, *Semotilus atromaculatus,* and the common shiner, *Notropis cornutus.* Very limited predation by birds was seen.

The experiment thus far has shown that under proper conditions salmon fry introduced into Duffin Creek will survive in good numbers, and complete 2 years of stream life.

An incomplete record of the descent of smolts during the spring of 1948 was obtained by means of a fish trap installed in the east branch about 8 miles above Lake Ontario and trap nets set near the stream mouth. Although the strength of spring floods made it impossible to operate the trap nets at the height of the floods, considerable information on the migration of smolts was obtained. The some 600 smolts captured near the stream mouth were nearly all 2-year-old salmon. Smolts marked in the upper trap were recaptured in the nets some 7 miles below 5 or more days later. It was shown that few smolts were lost during the 7-mile stream migration. The chief hazards seemed to be angling and the nets of sucker fishermen. Pike, *Esox lucius,* took a few of the smolts near the river mouth.

As smolts are definitely known to reach the lake, the capture of adult salmon is expected in the nets of the lake fishermen who have been requested to forward any salmon taken.

As the first smolts left Duffin Creek in 1946, it is possible that they may return to Duffin Creek this autumn. For this reason pound nets are now set at the stream mouth to catch all incoming fish. At time of writing only one salmon has returned. This fish was a 5-pound female with about 4,000 eggs. If salmon return to the stream in any numbers, investigation of the problem of natural spawning will be undertaken. As the majority of gravel beds suitable for spawning lie above dams which prevent the upward movement of fish, it will be necessary to devise a method to help the salmon over these obstructions. The east branch has better salmon production and fortunately only one dam some 8 miles from the mouth.

The planting of 1948 was varied from that of the other years. As it has been sufficiently well established that certain stream areas are more suitable for salmon production than others, only the better waters were planted in an attempt to get the best possible production of smolts. Also, 80,000 rather than 40,000 fry were planted. Additional fry planted in

experimental areas showed that a very high survival was possible by a selective planting of the shallow gravelly riffles with pools below to accommodate the fry as they become larger.

The project thus far has been purely experimental. If adult Atlantic salmon are found to ascend Duffin Creek in any numbers, it is proposed to stock suitable parts of a number of southern Ontario streams in an attempt to establish Atlantic salmon again in Ontario waters. Furthermore, information obtained from this experiment may be of value in the restocking of streams with Atlantic salmon elsewhere.

FERTILIZATION OF LAKES IN ALGONQUIN PARK, ONTARIO[1]

R. R. Langford

University of Toronto, Tortonto Canada

Abstract

A program of fertilization was begun in Algonquin Park in 1946 as part of an investigation of the factors controlling productivity in lakes. Four lakes have been fertilized and one other is used as a check. The response of phytoplankton and zooplankton populations to increased nutrients is indicated in this preliminary report. In each lake a marked increase in the net phytoplankton occurred in from 3 weeks to a month after the first application of fertilizer. Diatoms and flagellate protozoans showed the greatest increment. The rise in zooplankton organisms was relatively less than that of phytoplankton although the rotifer population did increase in all lakes.

Introduction

Considerable publicity has been associated with the artificial fertilization of fish ponds in the southern United States and of small lakes in Canada (Taylor, 1944; Smith, 1945). In these and certain sea-lochs in Scotland (Gross *et al.*, 1946), remarkable increases in fish production have been reported following the addition of inorganic fertilizers to both inland and marine waters. Since many of the lakes in the Canadian-shield area of Ontario are poor in dissolved minerals and low in productivity with respect to fish, an investigation is being made of the possibilities of increasing the yield of such lakes by fertilization. It is essential, for a complete analysis of the results of such an investigation, to follow in detail the changes in the complex biota and in the physical environment itself which may result from fertilization.

Four lakes in Algonquin Park are employed as experimental lakes for fertilization and one other lake is used as a check. Detailed analyses are being conducted to assess changes in (1) the dissolved chemicals, (2) the plankton, (3) the bottom organisms, (4) the forage fish, and (5) the game fish, in order to determine the fate of the augmented inorganic nutrients in the biomass of each of these lakes.

It was expected that the plankton would react first to supplemental inorganic nutrients since it is more directly dependent upon these materials than are the higher animals. This preliminary report deals with the 1946 and 1947 results and is restricted to a consideration of the changes in the plankton populations.

[1] Contribution from the Ontario Department of Lands and Forests, and the University of Toronto.

Acknowledgements

The investigation is part of the program of the Research Division of the Ontario Department of Lands and Forests, and has been supported by that organization since the project was begun in 1946. During 1946 chemical analyses were made by Canadian Industries Limited from which the fertilizer was purchased.

It is a pleasure to acknowledge the invaluable help of Mr. J. L. Price who has made all plankton collections and has enumerated many of the zooplankton samples, and of Mr. Alen McCombie who has counted the remaining catches of zooplankton and phytoplankton. Thanks are also due to the several members of the Ontario Fisheries Research Laboratory who have contributed in many ways to the furtherance of the project.

Operation

The four lakes treated received a 12-24-12 (nitrogen, phosphorus, potassium) fertilizer containing ammonium phosphate, ammonium nitrate, and potassium chloride. Cache Lake, with an area of 570 acres, had 5 tons of commercial fertilizer added to its shallow-water area in 1946 and again in 1947. It is planned to continue the fertilization of this lake annually for a number of years and to follow the utilization of inorganic chemicals and the changes in plankton and fish populations in a general manner. Three smaller lakes, each 100 acres or less in extent, were investigated in 1946 in order to measure their productive capacities prior to the addition of inorganic chemicals. They were fertilized with different amounts and at different times during the season of 1947 while the biological and chemical investigations continued. Costello Lake has not been fertilized and is considered a control in the series. Changes in the other lakes are being followed in greater detail than in Cache Lake. It is expected that from these lakes will come the more specific information on the fate of the inorganic materials added. Certain physical characteristics of the lakes together with the fertilization data for 1946 and 1947 are presented in Table 1.

Increases in Phytoplankton

The phytoplankton, as sampled by the Juday 10-liter plankton trap with a No. 20 silk bolting-cloth net, showed substantial increases in each of the lakes after the addition of fertilizer. The pattern of the response to augmented nutrients was similar in each lake although there were differences in the details of the results. This variation was expected since the lakes differ in their physical characteristics and also because the amount of fertilizer added relative to the volume of the epilimnion differed in each lake. Furthermore, in some lakes the fertilizer was applied but once, whereas in other lakes it was divided into 2 or 3 lots and was added at monthly intervals during the summer. A few of the differences in response of the phytoplankton may be pointed out. Since the quantitative data from plankton counting are voluminous, details are not included in this paper but are on file at the Ontario Fisheries Research Laboratory, University of Toronto.

The phytoplankton in Cache Lake showed a late-summer increase 3

weeks after the addition of 5 tons of fertilizer at the end of July 1946 (Fig. 1 and Table 2). The population was roughly doubled but numbers did not attain the June maximum for that year. The diatoms *Fragillaria, Tabellaria,* and to lesser extent *Melosira,* were mainly responsible for this late increase. In 1947 the lake received the first application on June 26 and the phytoplankton rose steadily to a maximum on July 18,—22 days

TABLE 1.—*Physical characteristics of the fertilized lakes, and data on fertilization for 1946 and 1947*

Lake	Area (acres)	Maximum depth (yards)	Epilimnion depth (yards)	Fertilization[1] (tons)	Dates of treatment	Calculated[2] concentration in epilimnion (p.p.m.)
Cache	570	30	5	5	July 30, 1946	0.53
Brewer	100	15	3	4.4	June 18, 1947 July 29, 1947	4.35
Cache	570	30	4–5	4.4	June 26, 1947 July 22, 1947 August 12, 1947	0.58
Kearney	80	19	3	5	July 1, 1947	6.28
McCauley	56	10	3	5	June 4, 1947 July 8, 1947 August 5, 1947	8.97
Costello	92	15	4	Unfertilized		

[1] Total fertilizer added for a particular year
[2] The theoretical concentration of the total soluble portion of the fertilizer (48 percent) in parts per million, with the assumptions that the total amount was added at one time, was completely dissolved at once, and was uniformly distributed in the epilimnion

later. The forms which showed this marked increase were *Tabellaria* and the flagellate protozoan *Dinobryon.* Two further applications of fertilizer were made on July 22 and August 12 but the population declined steadily throughout August and early September. A relatively heavy population of diatoms (*Tabellaria, Asterionella,* and *Melosira*) was again found in early October.

In Brewer Lake (Fig. 2 and Table 2) the population was low and decreased steadily throughout the summer of 1946, the year previous to fertilization. In 1947 the lake received its initial fertilization on June 18. The population began to increase by July 5 and reached an extremely high maximum on July 19, a month after fertilization. Numbers fell off rapidly after this peak. A second application on July 29 failed to halt the decline or to produce a second increase at a later date. The early rise in numbers in Brewer Lake was attributable to *Tabellaria* and *Asterionella,* but the peak numbers were made up almost entirely of *Asterionella.* Following the July maximum the diatoms decreased very rapidly but two flagellate protozoans, *Dinobryon* and *Synura,* showed considerable increase in numbers until August 9.

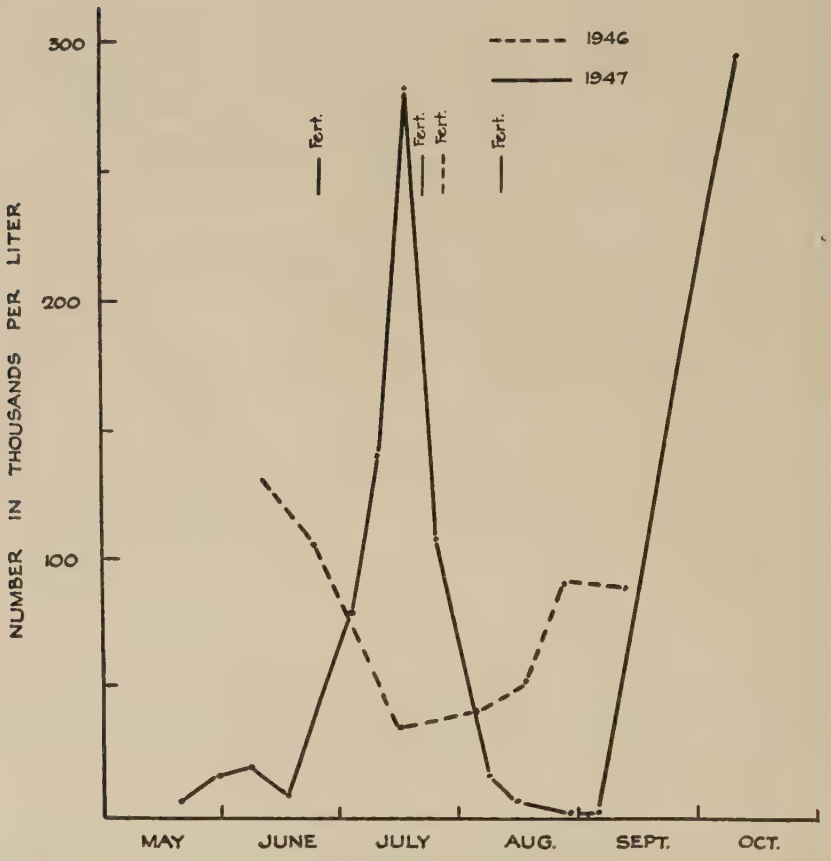

FIGURE 1.—Abundance of net phytoplankton, together with fertilization dates, Cache Lake, 1946 and 1947.

In Kearney Lake a fall maximum occurred in early September 1946. The main constituents were the diatoms *Fragillaria* and *Asterionella* together with *Dinobryon*. The lake received 5 tons of fertilizer on July 1, 1947, and a summer maximum of diatoms occurred 3 weeks later. *Tabellaria* continued to rise in numbers until the middle of August but *Asterionella* and *Melosira,* which were mainly responsible for the July 21 maximum, decreased after that date.

McCauley Lake showed two maxima in 1946, one in early July and the second in early September. As in the other lakes the forms responsible in both maxima were *Tabellaria, Asterionella,* and *Dinobryon*. The lake was first fertilized on June 4, 1947, and a maximum in the phytoplankton made up of the same three forms followed a month later. Two further

TABLE 2.—*Average numbers of net phytoplankton per liter, in the 0- to 8-meter strata of three lakes in Algonquin Park for 1946 and 1947*

Cache Lake

Date (1946)	Number	Date (1947)	Number
		May 20	6,300
		do. 29	16,200
June 10	132,100	June 7	19,400
do. 24	105,900	do. 17	11,700
		July 3	78,500
		do. 10	139,000
July 15	35,400	do. 18	282,300
do. 30	39,000	do. 25	107,700
August 9	43,300	August 8	16,000
do. 17	51,800	do. 15	6,200
do. 27	91,800	do. 28	1,900
September 13	87,700	September 5	2,400
		October 12	292,600

Brewer Lake

Date (1946)	Number	Date (1947)	Number
		May 28	1,500
		June 4	1,700
June 13	22,200	do. 12	530
do. 21	11,200	do. 20	420
do. 27	17,900	do. 28	1,200
July 3	11,200	July 5	12,400
do. 12	7,200	do. 12	221,100
do. 19	3,900	do. 19	812,300
		do. 25	698,700
August 4	1,200	August 2	108,600
do. 12	840	do. 9	33,800
do. 20	480	do. 23	2,200
do. 26	1,200	do. 29	1,600
September 3	2,400	September 6	270
do. 9	3,900	do. 27	410
		October 11	2,000

Costello Lake

Date (1947)	Number	Date (1947)	Number
May 10	120	July 17	43,200
do. 21	960	do. 24	44,500
do. 28	1,400	do. 31	117,900
June 4	1,500	August 7	80,600
do. 11	1,100	do. 14	88,000
do. 19	1,500	do. 27	2,400
do. 27	15,900	September 4	720
July 4	32,100	do. 27	120
do. 11	28,900	October 11	1,100

applications of fertilizer were made on July 8 and August 5. The phytoplankton decreased throughout July although *Tabellaria* continued to increase until July 21. The numbers of this genus fell off in late July and the total population remained at a low level throughout August to rise to a second small peak on September 10, slightly over a month after the last fertilization. *Dinobryon* and to a lesser extent *Asterionella* were responsible for this second increase in numbers.

Costello Lake, which had been chosen as a check for the series, was not fertilized. This choice was unfortunate as Costello receives part of its

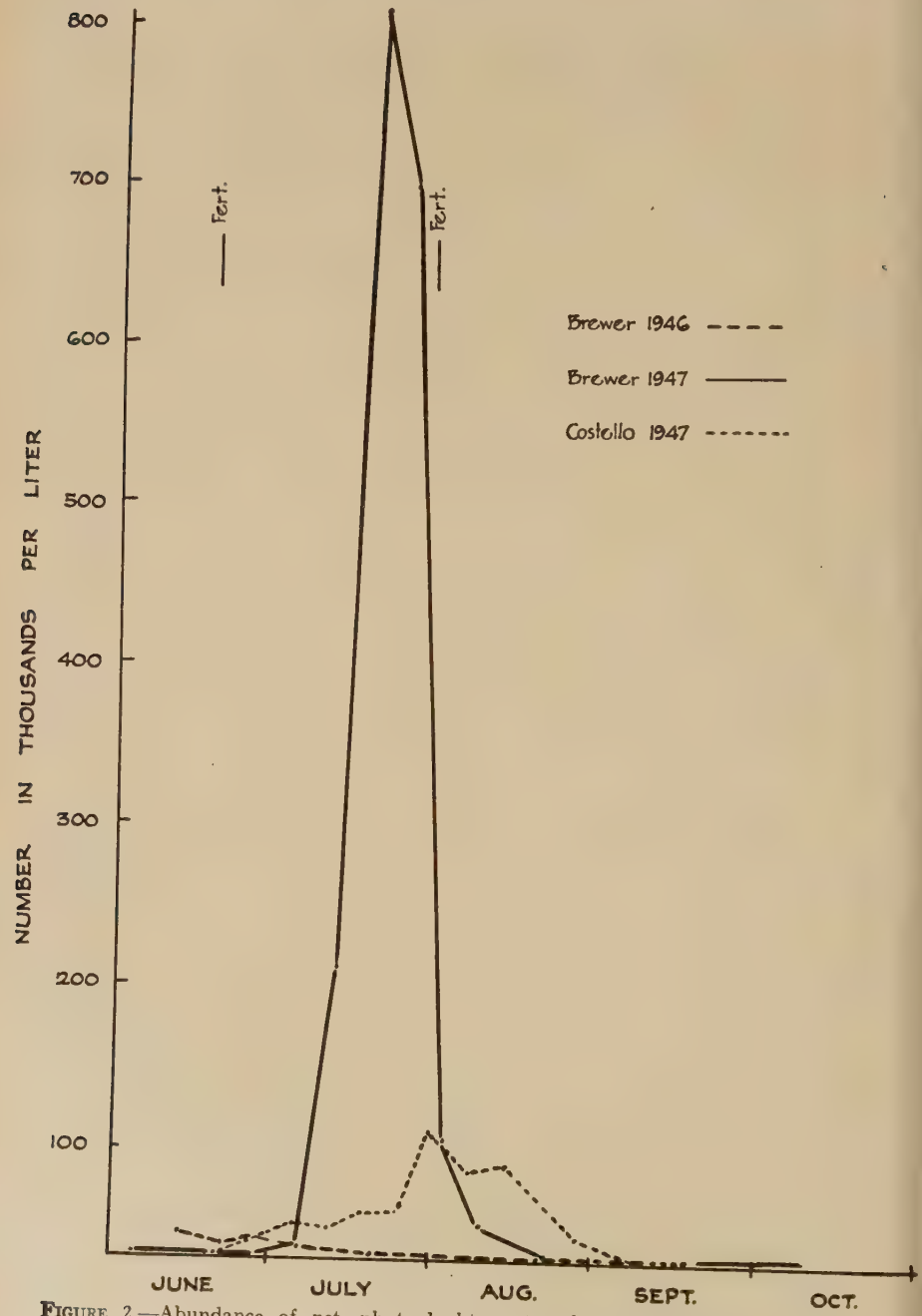

FIGURE 2.—Abundance of net phytoplankton, together with fertilization dates in Brewer Lake, 1946 and 1947, and in Costello Lake, 1947.

inflow from Brewer Lake and it may have received some inorganic nutrients from this source. The changes in the 1947 phytoplankton are illustrated in Figure 2. The population rose to a maximum on July 30, continued high until mid-August and then declined and showed no autumnal increase. The forms responsible for the peak abundance in early August were *Tabellaria* and *Dinobryon*. This situation is in contrast to that in Brewer Lake where *Asterionella* was the predominant diatom at the period of the maximum in that lake. The fact that maximum numbers were not reached in Costello until July 30, 6 weeks after the fertilization in Brewer Lake, lends support to the view that Costello received a secondary fertilization from the Brewer Lake outflow in 1947. All other lakes responded to fertilization by reaching maximum production of phytoplankton in from 3 to 4 weeks after the application of chemicals. In addition, none of the unfertilized lakes showed a midsummer maximum in 1946; this is in sharp contrast to Costello Lake in 1947.

In order to show the relative abundance of the phytoplankters of these lakes before and after fertilization, the average numbers per liter for the period from July to the end of September for the 2 years are plotted in Figure 3 and tabulated in Table 3. Cache Lake is omitted since it was

TABLE 3.—*Average numbers of net phytoplankton per liter, in the 0- to 8-meter strata of four lakes in Algonquin Park for the period from July 1 to September 30, 1946 and 1947*

Lake	Year	Number per liter
Costello	1947	32,700
Brewer	1946	7,000
	1947	135,400
Kearney	1946	47,000
	1947	74,600
McCauley	1946	19,100
	1947	31,100

fertilized in both years. Brewer Lake shows the greatest change in the year of fertilization—roughly a 20-fold increase over the previous year. Kearney and McCauley Lakes show significant but less marked changes; in each the phytoplankton increased about 1.5 times. It is surprising that McCauley Lake, which received by far the greatest amount of fertilizer relative to its volume, showed such a small increment in the net phytoplankton (retained by No. 20 bolting cloth). No explanation is suggested at present but it is hoped that the data for nannoplankton and the results of further investigation may clarify the situation.

INCREASE IN ZOOPLANKTON

The relative abundance of the zooplankton in Cache Lake in 1946 and 1947 is indicated in Figure 4 and Table 4. In 1946 the application of fertilizer was followed by a slight increase in zooplankton in about 3

weeks, at the time when the trap phytoplankton reached maximum numbers. This rise in numbers was particularly noticeable in the rotifer population. In 1947 the zooplankton increased markedly about 3 weeks after the first application of fertilizer (on June 26). This maximum was due mainly to greater numbers of copepods and rotifers. The population declined steadily to a minimum at the end of August when the population

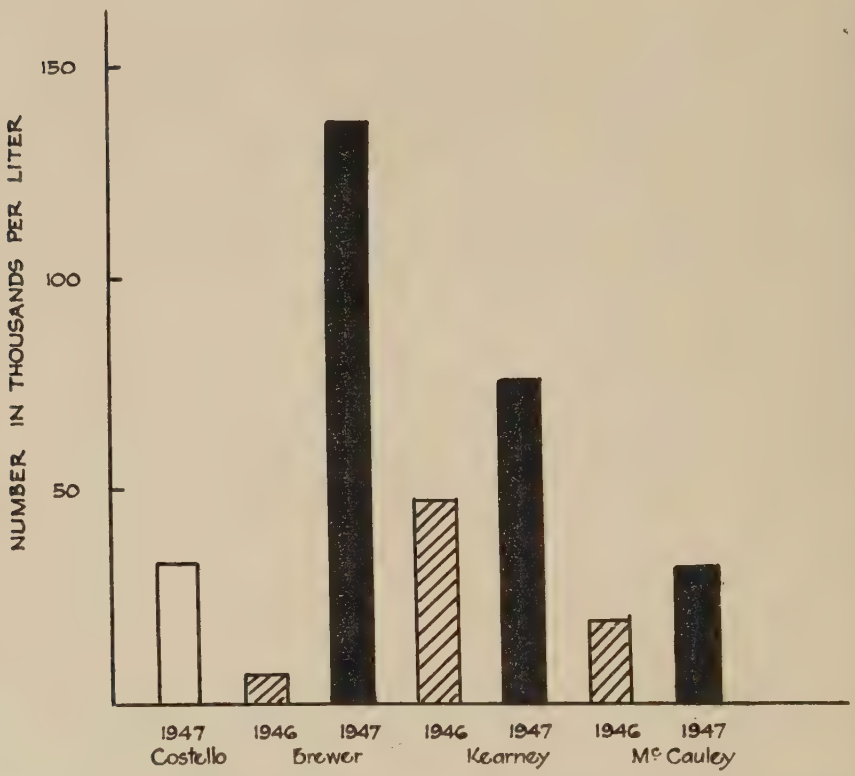

FIGURE 3.—Average abundance of net phytoplankton for the period from July 1 to September 30 in Brewer, Kearney, and McCauley Lakes, 1946 and 1947, and in Costello Lake, 1947.

again began to increase and was at a high level in early October. This second rise, which did not begin until a month after the final fertilization in 1947, was again the result of a pulse of rotifers together with *Cyclops* of the copepods.

Figure 5 and Table 4 indicate the relative abundance of the zooplankton in 1946 and 1947 in Brewer Lake. It is obvious that the 1947 population

was significantly greater than that of the previous year. The large increase in the 1947 population took place about a month after the initial fertilization and was practically restricted to the rotifers. The genera *Keratella, Notholca,* and *Polyarthra* persisted in abundance for 3 weeks, then decreased rapidly to negligible numbers. The copepod *Cyclops* increased materially some 6 weeks after the initial fertilization and persisted in large

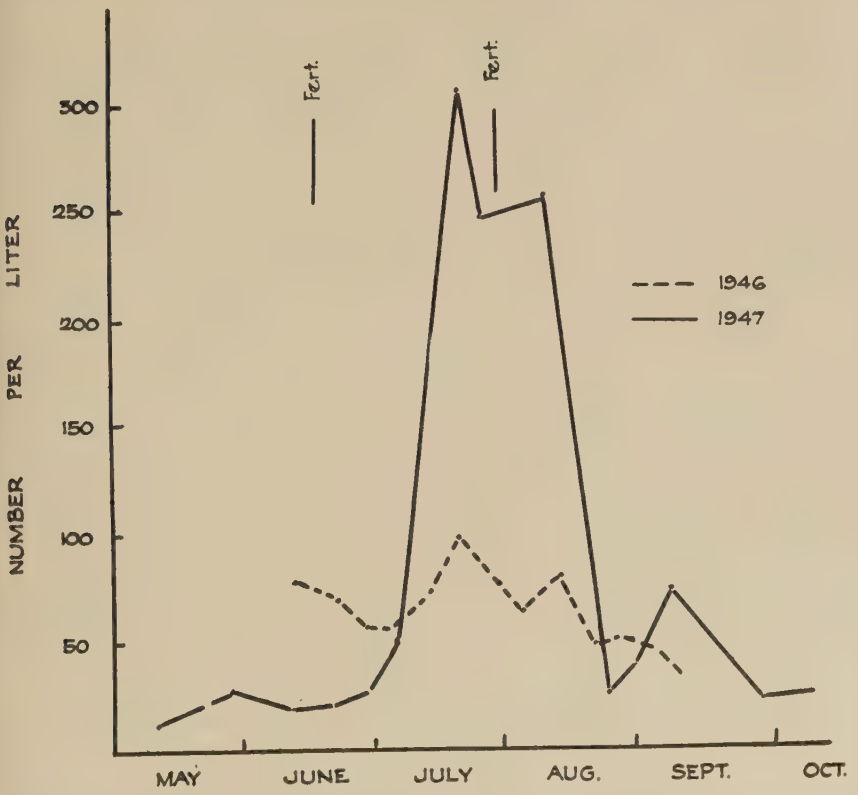

FIGURE 4.—Abundance of net zooplankton, together with fertilization dates, Cache Lake, 1946 and 1947.

numbers longer than the rotifers. The minor pulse in September was the result of increasing numbers of *Cyclops* and *Diaptomus*.

The zooplankton of Kearney Lake was also larger in 1947 than in 1946, although the increment was not great. The maximum population was reached 3 weeks after fertilization but the numbers decreased rapidly after that time. The rapid increase after fertilization was restricted almost entirely to the rotifers *Keratella* and *Polyarthra*.

In McCauley Lake the 1947 population was not significantly larger than that of 1946. Maximum numbers were found on July 14 more than 5 weeks after the initial application of fertilizer. The increase was general among most forms, both copepods and rotifers contributing to the maximum.

TABLE 4.—*Average numbers of zooplankton per liter, for Cache Lake and Brewer Lake for 1946 and 1947*

Cache Lake

Date (1946)	Number	Date (1947)	Number
		May 20	24
		do. 29	21
June 10	49	June 7	31
do. 24	40	do. 17	21
		July 3	27
		do. 10	41
July 15	40	do. 18	56
do. 30	40	do. 25	57
August 9	53	August 8	34
do. 27	28	do. 15	30
September 13	24	do. 28	13
		September 5	19
		October 12	50

Brewer Lake

Date (1946)	Number	Date (1947)	Number
		May 11	12
		do. 22	23
		do. 28	27
		June 4	22
June 13	79	do. 12	18
do. 21	68	do. 20	20
do. 27	56	do. 28	26
July 3	55	July 5	49
do. 12	69	do. 19	309
do. 19	97	do. 25	247
August 4	61	August 9	257
do. 12	80	do. 23	23
do. 20	47	do. 29	38
do. 26	51		
September 3	43	September 6	74
do. 9	33	do. 27	24
		October 11	26

SUMMARY AND CONCLUSIONS

It is clear that in each lake a marked increase in the net phytoplankton occurred in from 3 weeks to a month after the first application of fertilizer. In all instances the greatest increment was in the diatom and flagellate-protozoan populations. Also, a rapid decline followed the maximum and subsequent application of fertilizer failed to cause any further increase during the season. Cache Lake proved to be an exception in 1947 for an October pulse was observed 2 months after the last fertilization in that year. From the data presented it would appear that a single application of chemical fertilizer early in the spring was all that was utilized to advantage by the net phytoplankton during the summer season in these lakes.

The situation with respect to the zooplankton populations of the fertilized lakes differed to some extent from that of the phytoplankton. In all lakes the rotifer population increased in from 3 to 5 weeks after fertilization, a slightly longer time interval than that for maximum phytoplankton production. The relative increase in zooplankton after fertilization was much less than that in phytoplankton. In Brewer Lake only, was there a

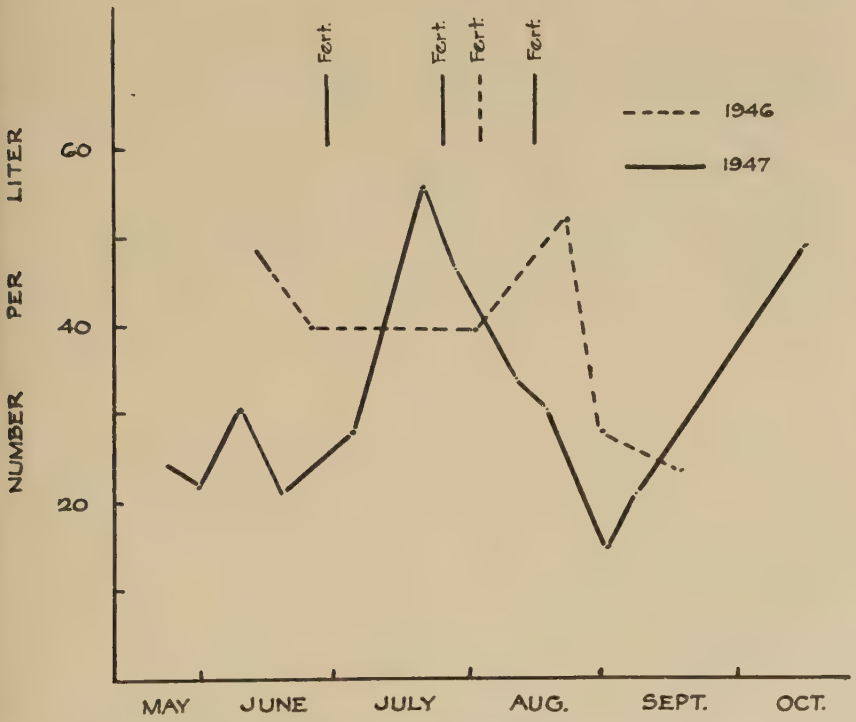

FIGURE 5.—Abundance of net zooplankton, together with fertilization dates, Brewer Lake, 1946 and 1947.

substantial increase in the zooplankton population in 1947. It is possible that the 1948 and future results will show increased zooplankton in the fertilized lakes, but from the data at hand it is concluded that fertilization for a single year has not materially augmented the zooplankton population in these lakes.

LITERATURE CITED

GROSS, F., J. E. G. RAYMONT, S. M. MARSHALL, and A. P. ORR
1944. A fish farming experiment in a sea loch. Nature, Vol. 135, pp. 482–485.

JUDAY, C., and C. L. SCHLOEMER
1938. Effect of fertilizers on plankton production and on fish growth in a Wisconsin Lake. Prog. Fish-Cult., No. 40, pp. 24–27.

KING, WILLIS
1943. Lake management in the Sandhills Wildlife Management Area. Trans. Am. Fish. Soc., Vol. 72 (1942), pp. 204–211.

MARSHALL, S. M., and A. P. ORR
1948. Further experiments on the fertilization of a sea loch (Loch Craiglin). Jour. Mar. Biol. Assoc., N.S., Vol. 27, pp. 360–379.

SMITH, M. W.
1948. Preliminary observations upon the fertilization of Crecy Lake, New Brunswick. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 165–174.

TAYLOR, B. W.
1944. Fertilizing lakes (Lecture delivered before the Anglers' Association of the Province of Quebec). 15 pp. [Mimeographed]

WALES, J. H.
1946. Castle Lake trout investigation. Cal. Fish and Game, Vol. 33, pp. 109–143.

FERTILIZATION OF NATURAL LAKES IN MICHIGAN [1]

ROBERT C. BALL

Department of Zoology, Michigan State College
East Lansing, Michigan

ABSTRACT

Inorganic fertilizer was applied to two state-owned lakes in northern Michigan, one a 4.3-acre trout lake and the other a 27.5-acre warm-water lake. Two nearby lakes were kept under observation as controls.

Fertilizer brought about a plankton-algae bloom the first summer in the warm-water lake and produced a very heavy growth of filamentous algae the second summer. The trout lake responded much less to the added nutrients; the reading of a Secchi disk was at no time less than 8.2 feet.

No appreciable oxygen depletion occurred during the winter following the first season of fertilization. Chemical analysis in February of the second winter showed severe oxygen depletion, with oxygen levels at less than 1 p.p.m. at all depths. An almost complete winterkill occurred in both fertilized lakes. No winterkill occurred in the control lakes.

INTRODUCTION

Since organic and inorganic fertilizers are known to be of value as tools of fishery management for farm ponds, it has been felt that an extension of their use to include certain natural waters should be made to determine whether an increase in the growth of fish would result from the added nutrients, and, if so, whether the expenditure of time and materials could be justified.

With approximately 11,000 lakes in Michigan (Brown, 1943) it does not seem that fertilization of many of them, especially the warm-water lakes, can be justified under present conditions. The adequate harvesting and proper balancing of the fish crop are perhaps more pressing questions of management than is an increase of the standing crop of fish.

It was the opinion of Dr. A. S. Hazzard, Director of the Institute for Fisheries Research, Michigan Department of Conservation, that the most likely field for lake fertilization in Michigan was in the relatively small trout waters which are of essentially low productivity. These lakes, because they support trout, have greater value to the angler than do lakes of similar size that support warm-water fish.

Lakes of the northern portion of the Lower Peninsula of Michigan, where soil conditions permit only meager farming, are generally low in pro-

[1] Contribution of the Michigan Institute for Fisheries Research and the Agricultural Experiment Station of Michigan State College. Authorized as Journal Article No. 978 (n.s.) from the Michigan Agricultural Experiment Station.

ductivity of fish as compared with lakes of southern Michigan. It was believed that these lakes had the greatest need for artificial enrichment and hence offered the best opportunity to evaluate adequately the effects of fertilizer on natural lakes.

Two pairs of lakes in the northern section of the Lower Peninsula of Michigan were selected for the fertilization experiment. North and South Twin lakes in Cheboygan County, were chosen as representative of relatively unproductive warm-water lakes in an area where the most important business is the resort and tourist trade. In a section that has many good trout streams these lakes offer the only pan-fish waters of the immediate area and as such are of importance locally. The other two lakes selected are trout waters, located about 20 miles south of the warm-water lakes in the state-owned Pigeon River Forest area, Otsego County. These lakes, also designated as North Twin and South Twin, had been included in an experimental management program (Eschmeyer, 1937) several years prior to the start of this project.

Description of the Warm-water Lakes

North Twin Lake (Cheboygan County).—This lake which is located in jack-pine plains of the Little Sturgeon River drainage, has a surface area of 27.5 acres and a maximum depth of 15 feet. The clear water seldom extends below a depth of 12 feet. The lake has no inlet or outlet. The bottom is pulpy peat except on the wind-swept shoal adjoining the narrow sand beach. The surrounding land, which is covered with second-growth pine and aspen, has no agricultural value. The lake does not stratify.

The fish present were bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), black bullhead (*Ameiurus melas*), yellow perch (*Perca flavescens*), minnows, smallmouth black bass (*Micropterus dolomieu*), and hybrids between the bluegill and pumpkinseed. The centrarchids were reported as growing at a normal rate for Michigan (Walter R. Crowe, unpublished data), but they appeared thin and few large ones were present, and the perch showed definite signs of stunting. The lake had a poor reputation for fishing.

The aquatic plants were sparse and consisted chiefly of two species of pondweed (*Potamogeton amplifolius* and *P. natans*) and the white water lily (*Nymphaea odorata*).

South Twin Lake (Cheboygan County).—This lake, which is situated about 500 feet south of North Twin Lake, is separated from it by a low ridge. Although larger (54 acres), it has a maximum depth of only 4 feet. The fish population included largemouth black bass (*Micropterus salmoides*), pike (*Esox lucius*), and bluegill. The fish of the lake were not stunted and the fishing was reported as "fair" at the time the fertilization of North Twin Lake was undertaken.

From the age of some of the game fish from the lakes and reports of sportsmen of the area it was evident that there had been no winterkill in these lakes for at least 10 years.

Description of the Trout Lakes

South Twin and North Twin Lakes in Otsego County are small solution lakes. They are of similar size, shape, and chemical content. The south lake has a surface area of 4.3 acres and a maximum depth of 39 feet. The steep basin slopes of both lakes have firm sand bottom to a depth of 15 feet; below this depth there is a thin covering of muck. Sparse stands of both broad-leafed and narrow-leafed potamogetons are scattered around the rims to a maximum depth of 20 feet.

The lakes have no inlet or outlet. Their levels depend upon the ground-water level since there is practically no surface drainage. These trout lakes are a scenic attraction due to the contrast between their extremely clear blue waters and the green of the surrounding large pines.

At the beginning of the experiment the lakes had fish populations which included many small yellow perch, minnows, a few large rainbow trout (*Salmo gairdnerii*), brown trout (*Salmo trutta*), and brook trout, (*Salvelinus fontinalis*). Presumably the minnows and perch were brought in by fishermen, either intentionally or as bait; the brown trout and rainbow trout were remnants of plantings made before the policy of introducing only brook trout in lakes was established. Both lakes are stocked each fall with fingerling brook trout. Trout fishing has not been good for some time because of the competition and predation of the perch.

Analysis, Concentration, and Distribution of Fertilizer

On the basis of soil samples analyzed at Michigan State College it was recommended that a high-nitrogen, high-phosphorous, commercial fertilizer (10-6-4) be applied. A tentative fertilization schedule at 3-week intervals proved satisfactory. The fertilizer was spread on the larger lake (North Twin, Cheboygan County) from a moving boat, and on the smaller lake (South Twin, Otsego County) from shore. Fertilization was carried on from June until September 1946, and from May until August 20, 1947.

The concentration of fertilizer to be applied during the summer of 1946 was established at 2 p.p.m. per week. The actual weights were 2,800 pounds for each application on the warm-water lake and 400 pounds for the small trout lake. This quantity proved to be satisfactory in the shallow North Twin Lake but was not adequate to bring about a plankton bloom in the colder, deeper water of South Twin Lake. In 1947 the amount of fertilizer for the trout lake was increased to 3 p.p.m. per week. An increase in the amount of particulate organic matter resulted but there was no bloom.

Chemical and Biological Effects of Fertilization—Summer Conditions

Warm-water lakes.—Chemical analyses of the fertilized warm-water lake were made at 3-week intervals during the summer of 1946, and at weekly intervals during the summer of 1947. The results of these analyses

(Ball and Tanner, MS) will appear elsewhere, but it may be noted that oxygen was present from top to bottom of the lake during the entire open-water season and that the water was moderately hard (50 p.p.m.). This shallow, warm-water lake responded to the addition of fertilizer shortly after the first application and maintained a heavy bloom of plankton algae throughout the summer; the Secchi-disk reading was 18 to 36 inches. The sparse beds of higher aquatic plants became covered with algae, turned brown, and died.

The pulpy-peat bottom, which came within a foot of the surface at the shallow end of the lake, appeared to liquefy as the first summer of fertilization progressed. No quantitative measure was made but observations indicated a change in its color and physical nature which is believed to be associated with active decomposition, presumably brought about by the addition of nitrogen and phosphorous.

In many respects the results for the second summer were greatly different. Until midsummer plankton algae were scarce in the lake, but great mats of filamentous algae covered the shallow areas. This growth died about midsummer, and for a period of approximately 10 days the dead and decaying mat drifted about the lake creating an unsightly and malodorous condition. Following the disintegration of the filamentous algae the lake became cloudy with plankton algae for the remainder of the summer.

Trout lakes.—Chemical analyses of the two trout lakes,made in June 1946 just prior to the first application of fertilizer, showed them to be similar in all respects. The total alkalinity was 48 p.p.m. in the south lake and 42 p.p.m. in the north lake. No further analyses were made until late October of the same year at which time both lakes were in the late stages of the fall overturn and conditions were uniform from top to bottom. The only change noted was in the higher total alkalinity (increase from 48 to 58 p.p.m.) in the fertilized lake while the alkalinity of the unfertilized lake was 41 p.p.m.

The four series of chemical analyses made during the summer of 1947 showed changing conditions that reached a peak in August, the period of the summer considered to be the most critical for trout lakes in Michigan. The physical and chemical conditions recorded for the lakes in August 1947 are shown in Table 1.

A tendency toward eutrophication in South Twin, the fertilized trout lake, can be seen from the data in Table 1. The thermocline was higher with an accompanying oxygen depletion in the hypolimnion. The thermocline extended from a depth of about 8 to approximately 20 feet, while in the north lake (unfertilized) it was of the same thickness but the upper limit was 18 feet below the surface and the lower limit at 30 feet (Fig. 1).

In the fertilized lake depletion of oxygen near the lower level of the thermocline limited the fish of the lake to the stratum above a depth of 20 feet, while in the untreated lake there was sufficient oxygen to support fish in the upper 30 feet (Fig. 2). However, the strata considered as trout

water were of almost identical thickness in the two lakes; they differed only as to the depth at which they occurred.

The temperature of the upper 15 feet in South Twin (fertilized) was lower than in North Twin at the time of the chemical analysis in August. This lower temperature may be attributed to the absorption of light rays by plankton organisms, which resulted from fertilization. At the time the

TABLE 1.—*Chemical and temperature data for two trout lakes, Otsego County, August 20, 1947*

Depth (feet)	North Twin Lake (unfertilized)						South Twin Lake (fertilized)					
	Temperature (°C.)	O_2	CO_2	Alkalinity[1] P.	Alkalinity[1] M.O.	pH	Temperature (°C.)	O_2	CO_2	Alkalinity[1] P.	Alkalinity[1] M.O.	pH
S[2]	25.0	9.3	0	0	38	7.4	25.0	9.2	0	4	72	7.3
6	....	...	...	...	..	...	24.5	...	...	...	..	...
9	....	...	...	...	..	...	22.4	...	...	...	..	...
12	....	...	...	...	..	...	19.0	...	...	...	..	...
15	24.5	...	...	...	..	...	14.3	...	...	...	..	...
18	23.5	8.8	0	0	36	7.0	10.1	7.3	3.0	0	72	7.0
21	18.1	...	...	...	..	...	8.6	2.2	...	...	..	...
24	12.5	...	...	...	..	...	8.1	0.0	...	...	..	...
27	8.1	...	...	...	..	...	7.8	...	...	...	..	...
30	7.5	8.0	...	...	..	...	7.5	...	...	...	..	...
33	7.1	0.0	5	0	39	6.9	7.1	0.0	7.0	0	78	6.7
36	7.1	...	...	...	...	...	7.1	...	...	...	..	...

[1] P = phenolphthalein alkalinity; M.O. = methyl-orange alkalinity
[2] Surface

temperature series was taken the Secchi-disk reading was 8.2 feet in the fertilized lake and 22.1 feet in the unfertilized lake.

A lowering of water temperature was noted by Eicher (1947) following an application of nigrosine in an experiment on the control of aquatic weeds. He attributed the lower temperature to the reduced penetration of infra-red rays as a result of the dye. This maintenance of a temperature closer to that accepted as suitable for trout water is desirable. Nevertheless, the fact that trout were observed rising on the surface of the untreated lake in which the upper 20 feet were at a temperature above 68° F., indicates that the warmer waters did not serve as a complete barrier to them.

The biological effects of the fertilizer on the trout lake were markedly different from those observed on the warm-water lake. At no time in the two summers was the Secchi-disk reading less than 8 feet. That the suspended organic matter increased in this lake is shown by comparison with its control, in which the Secchi disk was visible at 20 feet or more during the entire summer.

In the fertilized lake the logs, stones, and higher aquatic vegetation were heavily coated with filamentous algae. The plants were covered to such an extent that growth was limited and many died. This algal covering created an unsightly condition when it loosened and floated to the surface during the latter part of the summer.

Chemical and Biological Effects of Fertilization—Winter Conditions

Observations of 1947.—A check on the warm-water lakes was made in January 1947 at which time the chemical analyses showed neither a severe depletion of oxygen in either lake nor high concentrations of carbon dioxide. The oxygen level in the north (fertilized) lake was somewhat higher than

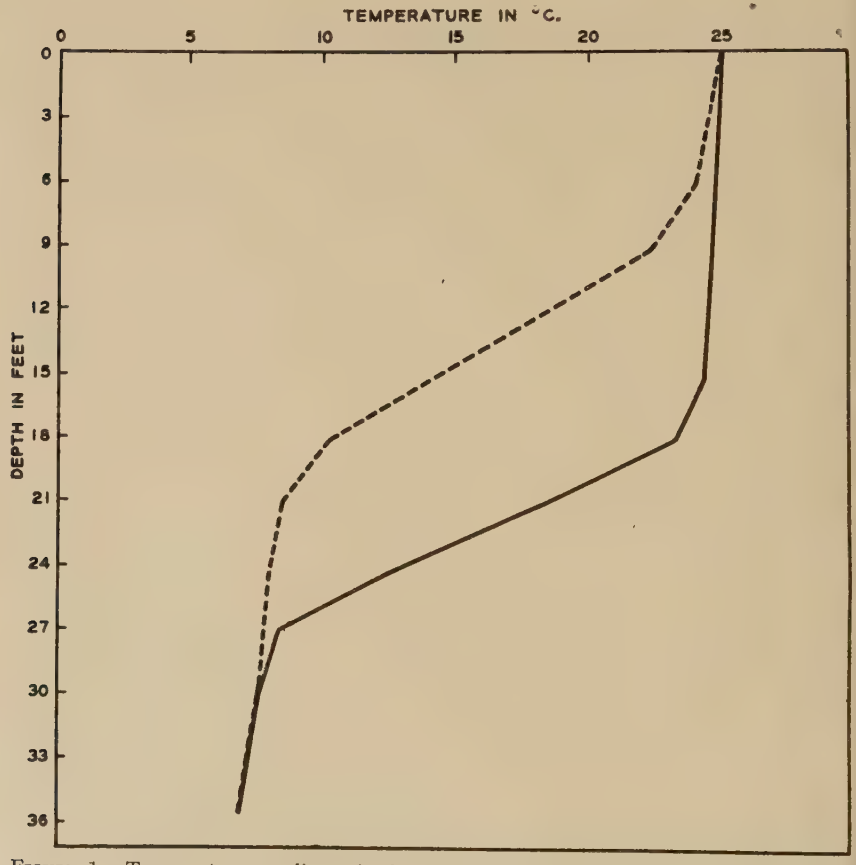

Figure 1.—Temperature gradients in fertilized (broken line) and unfertilized (solid line) trout lakes, August 1947.

in the south lake, probably because wind action removed part of the snow. Greenbank (1945) found that ice, even though cloudy, permits the penetration of a considerable amount of light, whereas even a few inches of snow on the ice reduces the amount of light reaching the lake to a point that no photosynthesis occurs.

No check on the trout lakes was made at this time as deep snow made them inaccessible. All lakes were visited at the time the ice cover was breaking up and no dead fish were seen.

Observations of 1948.—An examination was made of all four lakes during the last week of February 1948. This period of the winter is believed to be the most critical one as the snow and ice cover has been on almost its

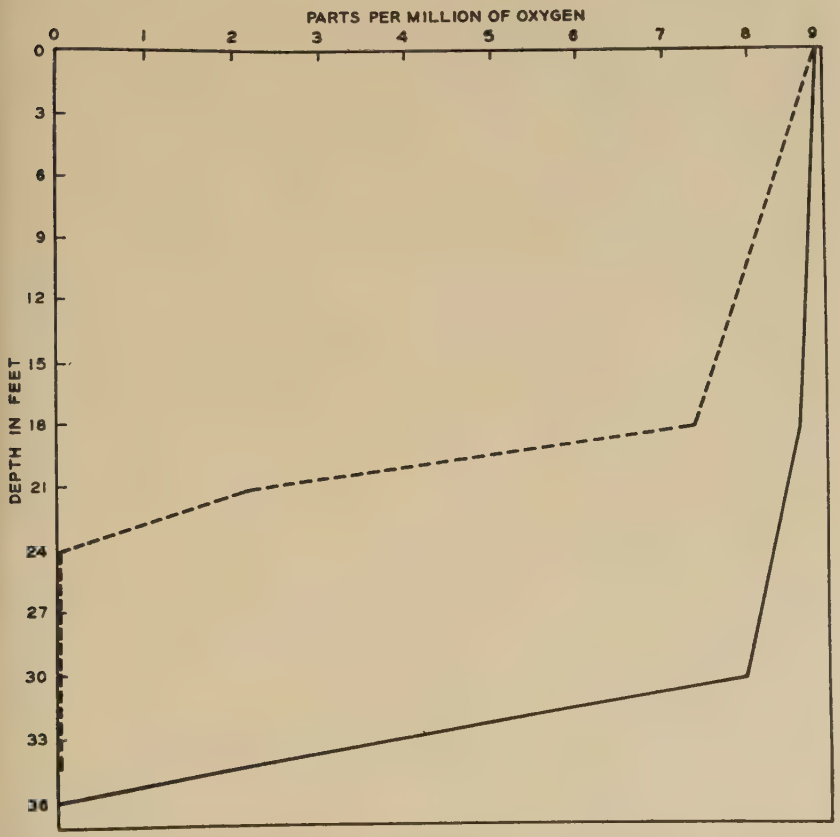

FIGURE 2.—Difference in oxygen concentration in fertilized (broken line) and unfertilized (solid line) trout lakes, August 1947.

maximum length of time and winter stagnation is at the maximum.

At the time of the 1948 examination the warm-water lakes were covered with 7 inches of clear ice on top of which were about 8 inches of snow ice. An analysis of the water of the north lake showed the oxygen concentration to be extremely low—0.7 p.p.m. at a depth of 2 feet and 0.2 p.p.m. at

10 feet. The carbon-dioxide level was high—40 p.p.m. at the 10-foot level. When the ice cover was broken the odor of decay was very strong and many dead phantom-midge larvae (*Chaoborus*) floated into the hole. Samples from greater depths indicated the presence of a considerable amount of hydrogen sulfide.

Bottom samples taken by means of a dredge at several locations on the lake revealed that many species of invertebrates, including scuds, damselflies, dragonflies, caddisflies, and adult beetles were dead. Larvae of the large midge, *Chironomus plumosis,* were alive but completely inactive.

No dead fish were noted at this time, but large numbers were found at a later visit just prior to the breakup of the ice. A check during the following spring and summer revealed that a small number of perch had survived the unfavorable conditions, but most fish had died.

A chemical analysis of the south lake revealed conditions that were similar in many ways. The oxygen level had been reduced to 0.3 p.p.m. at several locations in the lake. (The oxygen analyses were all made in duplicate and aerated samples run as checks.) On this lake the carbon-dioxide concentrations were low (8 p.p.m.) and no odor of decay or hydrogen sulfide was detected. No dead insects were found and a check at the time of the break-up of the ice revealed no dead fish. It is difficult to believe that oxygen concentrations as low as these would not cause the death of fish, but Cooper and Washburn (1949) have indicated that fish can tolerate oxygen concentrations lower than are generally regarded as lethal.

The trout lakes were visited in 1948 during the same period that the warm-water lakes were checked and chemical analyses were made on both lakes. Both lakes had a cover of clear ice about 10 inches thick and of snow about 8 inches deep.

Conditions on the unfertilized lake, North Twin, were altogether satisfactory for the survival of fish. Oxygen was ample for aquatic life to a depth of 21 feet or more and the carbon-dioxide concentrations were low.

Conditions were decidedly different in the fertilized lake, South Twin, where the oxygen did not exceed 0.6 p.p.m. at any depth and was less than 0.2 p.p.m. at a depth of 3 feet. The carbon-dioxide level was 18 p.p.m. at 3 feet. Here, too, the odor of decay was strong and dead *Chaoborus* floated into the hole in the ice cover. No fish were recovered at this time but many dead fish were found at the time of the breakup of the ice in April 1948. The oxygen concentrations in the two lakes at the critical stage are shown in Table 2 and Figure 3.

Growth of Fish in Fertilized Lakes

The winterkill terminated the study of the effects of fertilization on the growth of fish before enough evidence had been collected to enable us to evaluate adequately the several factors to be considered in such an investigation. However, from the examination of the scales (Ball and Tanner, MS) collected during the 2 years of the experiment, and after the winterkill, it is evident that the growth rate of the fish had increased considerably.

TABLE 2.—*Oxygen concentration in parts per million, in two trout lakes, February 1948*

Lake	Depth (feet)										
	S	3	6	9	12	15	18	21	24	27	30
North Twin Lake (unfertilized)	0.8	0.2	–	0.0	...	...	...	...	...	...	...
South Twin Lake (fertilized)	7.8	–	–	–	–	8.2	–	5.1	0.7	–	0.2

It is possible that the fertilization had an adverse effect on the reproduction of the fish. During the 1947 spawning season of the centrarchids the entire shoal area of North Twin Lake (Cheboygan County) that was

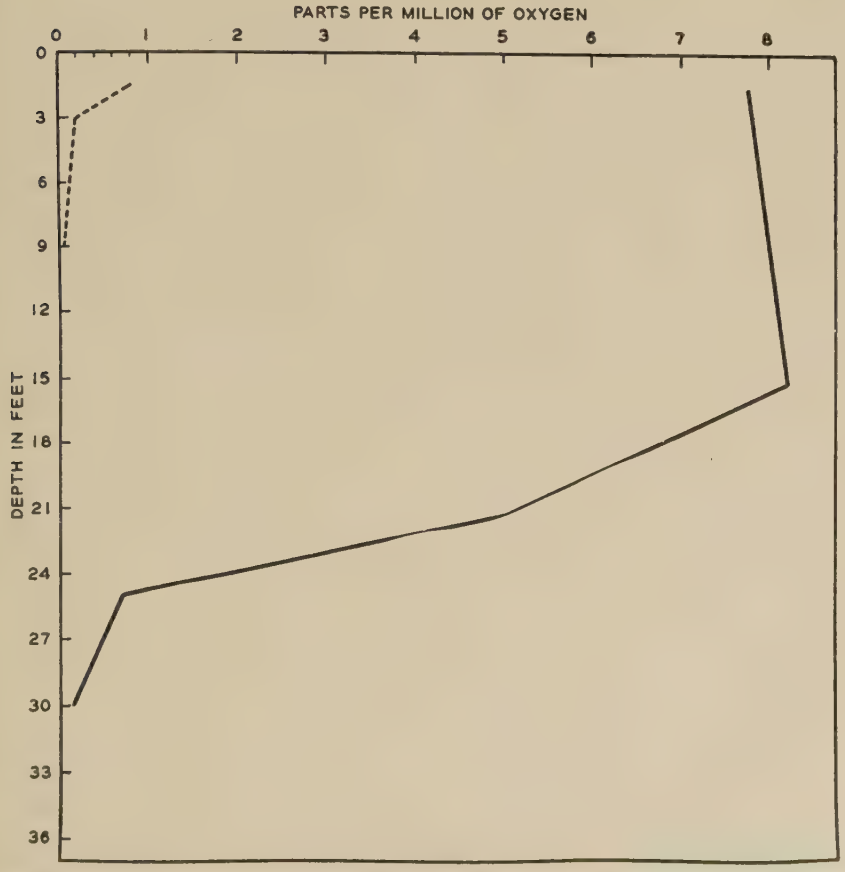

FIGURE 3.—Oxygen concentration in fertilized (broken line) and unfertilized (solid line) trout lakes during late-winter stagnation, 1948.

formerly suitable for spawning was covered with a dense mat of filamentous algae that appeared to interfere with nest building. The nests examined were relatively small openings cleared in the algae. It was observed also that many apparently active nests were abandoned because of envelopment by the algae. There was some spawning activity after the filamentous algae was gone but extensive seining late in the season yielded few young-of-the-year fish.

The experimental application of fertilizer to a trout lake in New Brunswick (Smith, 1948) appeared to have no ill effects during the winter following the first year's fertilization. It was presumed in the report on this lake that the volume of invertebrates in the bottom fauna had been increased by the fertilizer since the average volume of food in trout stomachs was 4½ times the average for the same period of the preceding year. That fertilizer will considerably increase the invertebrate fish-food organisms has been shown (Ball, 1949) by recent work on small ponds in Michigan.

Recommendations Concerning the Fertilization of Lakes in Michigan

The fertilization of two unproductive northern Michigan lakes resulted in a severe winterkill in both following the second summer of fertilization. That the addition of fertilizers brought about this kill seems certain since no similar mortality occurred in the two lakes that served as controls. Whether or not less fertilizer would have produced an increase in the growth rate of the fish without leading to oxygen depletion during the winter is not known; the problem is under investigation at the present time.

At no time did the plankton bloom in North Twin Lake (warm-water lake) reach the concentration that has been recommended as the level to be maintained in southern ponds (Swingle and Smith, 1942), and the bloom attained was always on the wane before the end of the 3-week period between applications of fertilizer.

No bloom was present in South Twin (trout lake) at any time during the two summers.

From these experiments it appears that by artificial enrichment a trout lake can be so altered that its characteristics approach those of a eutrophic, or water-warm fish lake.

Hasler (1947) has stated many of the undesirable consequences that can result from fertilization and as examples has cited European lakes in which coarse-fish species have replaced the more desirable trout and coregonids as a result of urban drainage.

The changes noted in South Twin Lake may be only transitory, but until more evidence as to their duration is obtained it seems that fertilization of lakes in the latitude of Michigan should be confined to experimental work.

In considering the fertilization of a lake the nuisance factor of a high production of filamentous algae should not be overlooked. This growth is extremely objectionable to fishermen, swimmers, boat operators, and owners of lake-shore property.

From these experiments it is evident that the fertilization of natural lakes can have unfavorable as well as favorable results. Until such a time as we can predict more accurately the amounts of fertilizer adequate to increase the productivity of a lake without the accompanying depletion of oxygen during the periods of ice cover, and can predict or control the type of algae that will be produced, it does not appear wise to sanction or encourage the indiscriminate fertilization of lakes.

Literature Cited

Ball, Robert C.
1949. Experimental use of fertilizer in the production of fish-food organisms and fish. Mich. State Coll., Agr. Exp. Sta., Tech. Bull. 210, 28 pp.

Brown, C. J. D.
1943. How many lakes in Michigan? Mich. Cons., Vol. 12, No. 5. p. 8.

Cooper, Gerald P., and George N. Washburn
1949. Relation of dissolved oxygen to winter mortality of fish in Michigan lakes. Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 23–33.

Eicher, George
1947. Aniline dye in aquatic weed control. Jour. Wildliife Man., Vol. 11, No. 3, pp. 193–197.

Eschmeyer, R. W.
1938. Experimental management of a group of small Michigan lakes. Trans. Am. Fish. Soc., Vol. 67 (1937), pp. 120–129.

Greenbank, John
1945. Limnological conditions in ice-covered lakes, especially as related to winterkill of fish. Ecol. Mon., Vol. 15, No. 4, pp. 343–392.

Hasler, Arthur D.
1947. Eutrophication of lakes by domestic drainage. Ecol., Vol. 28, No. 4, pp. 383–395.

Smith, M. W.
1948. Fertilization of a lake to improve trout angling. Fish. Res. Bd. Can., Prog. Reports Atl. Coast Stations, No. 43, pp. 3–6.

Swingle, H. S. and E. V. Smith
1942. Management of farm fish ponds. Ala. Agr. Exp. Sta., Bull. 254, 23 pp.

A NOMOGRAPH FOR THE COMPUTATION OF THE GROWTH OF FISH FROM SCALE MEASUREMENTS

Ralph Hile

U. S. Department of the Interior, Fish and Wildlife Service
Ann Arbor, Michigan

Abstract

Directions are given for the construction and operation of a nomograph that can be employed for the computation of the growth of fish from scale measurements regardless of the nature of the body-scale relationship, so long as that relationship is known. The essential feature of the nomograph that makes rapid calculations possible is a ruler on which the graduations are in terms of length with the distance of each length graduation from the 0 graduation equal to the corresponding theoretical scale measurement. The chief advantage of the nomograph lies in the fact that the calculation of the lengths for all years of life of an individual fish requires only one setting of the single movable part.

Introduction

As the use of scale measurements for the computation of the growth histories of fish has expanded, interest has arisen in nomographic devices by means of which the labor entailed in the necessary calculations may be lessened. When scale measurements are recorded in terms of a standard unit of length (usually millimeters) and when the body-scale relationship of the species or stock of fish under investigation is linear, computations by nomograph have little if any advantage over numerical calculations, provided a modern high-speed calculating machine is available. A nomograph is to be recommended or is essential, however, when the positions of the focus (if radial measurements are made), the several annuli, and the edge(s) of the scale are recorded by means of marks on a cardboard strip and/or the mathematical relationship between body length and scale measurement is not described by a straight line.[1]

The procedures offered for the computation of growth histories for species or stocks of fish in which the body-scale relationship is non-linear have not been simple. Some have required a combination of nomographic or numerical computations and reference to a detailed tabulation of corresponding body lengths and scale lengths (Segerstråle, 1933; Hile, 1941). Others have involved the use of nomographs with logarithmic scales and moving parts whose position must be shifted each time the length is computed for an individual year of life (Monastyrsky, 1930; Fry, 1943). The

[1] See Van Oosten (1941) for a recent review of the observations of various investigators on the nature of the body-scale relationship. Still other mathematical relationships between body length and scale measurement have subsequently been derived by Fry (1943) and Carlander (1945a, b).

difficulties imposed by repeated reference to detailed tabulations, the reading of logarithmic scales, and the frequent manipulation of moving parts can be relieved by the use of the nomograph to be described in this paper. The chief advantages of the proposed procedure are: it can be employed regardless of the nature of the body-scale relationship; and the calculated lengths can be read for all years of life of an individual fish from a single setting of the one movable scale. The major disadvantage lies in the fact that a scalar representation must be prepared of each body-scale relationship on the basis of which computations of growth are to be made.

The concept behind this nomograph is extremely simple, and the idea of applying it to growth-rate studies is not new. I demonstrated it in March 1944 before the Michigan Academy of Science, Arts, and Letters and subsequently have assisted fishery biologists in the preparation of similar ones. Furthermore, in the same year as the demonstration Carlander and Smith (1944) proposed the use of the same principle. Unfortunately those authors did not publish an illustration of their "specialized nomograph" or give a specific example of its use; there is some evidence that the true significance of their important suggestion may have escaped many of their readers.

The first draft of the present paper had been completed but plans for its publication were abandoned at the time the article by Carlander and Smith appeared. Subsequent conversations with fishery biologists and inquiries coming to me regarding nomographic devices (some of which indicate continued interest in highly complicated nomographs) have led me to conclude that the publication of a detailed account of the construction and operation of this equipment might prove useful to the numerous investigators who are for the first time undertaking studies of age and growth in this period of rapidly expanding research programs. Contributing to the decision was the belief that the apparatus described here may prove somewhat more convenient to prepare, use, and store than the one suggested by Carlander and Smith. They proposed a "nomographic table" of the body-scale relationship, whereas the essential feature of my own nomograph is a specially prepared "body-scale ruler."

Dr. John Van Oosten made helpful suggestions on the wording of the original manuscript. Dr. Frank W. Jobes prepared the body-scale ruler and Mr. Howard J. Buettner drew Figure 2.

Construction of the Nomograph

The nature of the calculating device will be illustrated by the description of its preparation and use for the computation of the growth of the Nebish Lake (Wisconsin) rock bass. In an earlier paper (Hile, 1941) it was determined that the relationship between standard length (L) in millimeters and the magnified (X40.5) scale radius (S) in millimeters was described satisfactorily in that stock by the equation:

$$L = 5.84011\ S^{0.695992}$$

The method of calculating growth employed in that paper required the preparation of a table of solutions of the above equation. This same table provides the data necessary for the construction of a scalar representation of the body-scale relationship.

In the scalar representation just mentioned, the graduations are labeled in terms of fish length, but the distance of each length graduation from the 0 graduation is the corresponding scale length (see Fig. 1). For example, at the magnification used to obtain the measurements employed for deriving the equation, the length of the scale of a fish 20 millimeters long would be 5.9 millimeters and the length graduation labeled 20 would accordingly be 5.9 millimeters from $L = 0$. Similarly, since $S = 9.5$ when $L = 28$, the graduation for the length of 28 millimeters would be 9.5 millimeters from 0, and the distances from 0 of the graduations for lengths of 43, . . . 112, . . . 183, . . . millimeters would be 17.6, . . . 69.7, . . . 141.1, . . . millimeters.

In actual practice, the graduations of a ruler based on measurements such as those given in the preceding paragraph would be badly crowded. Even if the scale of the ruler could be prepared accurately, readings could be made from it only with difficulty and with a high degree of possible error. In order to obtain a ruler with more widely spaced graduations the theoretical scale lengths of rock bass at different body lengths were multiplied by 1.15 and the resulting numbers treated as tenths of an inch rather than as millimeters. The theoretical scale lengths so determined were the equivalent to measurements that would have been obtained at the magnification 118.3—that is, 40.5 x 2.54 x 1.15 = 118.3. (The total "effective" magnification would, of course, need to be less in the preparation of a ruler for a species that reaches a much greater size than does the rock bass.) The reason for the use of the factor 1.15 to add to the increase obtained by treating millimeters as tenths of an inch will be brought out later, when the operation of the nomograph is explained.

The photographs of sections of the scale (Fig. 1) bring out the rather wide variations in the spacing of the graduations. Aside from irregularities traceable to the rounding of figures, the distance between graduations becomes greater with increase in the length of the fish. That this relationship must hold is obvious from the body-scale equation.

The ruler was drawn on good quality of white drawing paper and mounted with rubber cement on a thin strip of spring steel three-quarters of an inch wide. The slotted end of the steel strip extended about an inch beyond the 0 graduation of the scale.

The nomograph for the computation of the growth of the rock bass consists of the ruler, the preparation of which has just been described, lying on a background of 0.1-inch cross-section paper. The slotted end of the steel strip is mounted on a flat brass cylinder set flush in the board on which the paper is mounted and is held in position by a small bolt passing through the axis of the cylinder and fitted with a washer and wing-nut.

Operation of the Nomograph

The use of the nomograph will be illustrated by a description of the calculation of the growth histories of two Nebish Lake rock bass, both in the ninth year of life and 183 millimeters long at the time of capture.

The first of these fish had a total scale measurement (anterior radius) of 128 millimeters (Specimen No. 263, Table 1; see also Fig. 2). As the

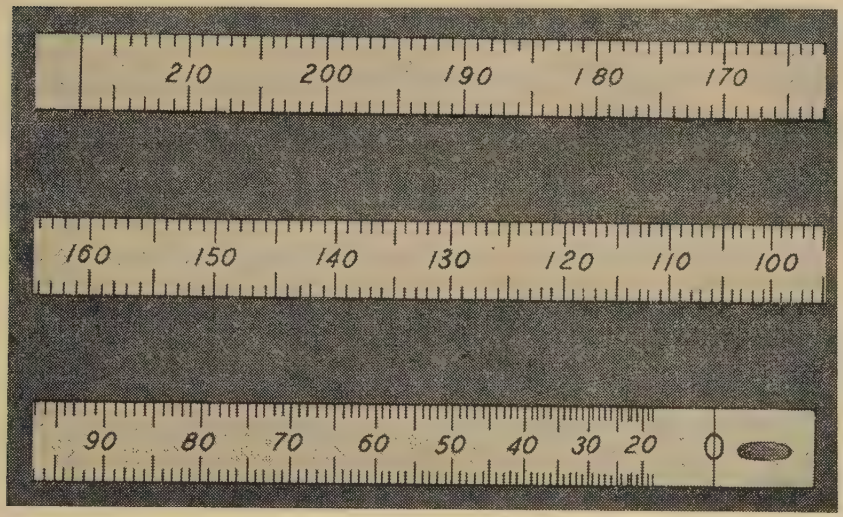

Figure 1.—Photograph of sections of the "body-scale ruler" for the Nebish Lake rock bass. No calculated lengths were less than 20 millimeters; hence graduations were omitted between 0 and 20.

initial step in the calculation, the ruler is placed in such a position that its 0 graduation falls on the vertical 0 line of the paper and the length-graduation 183 falls on the vertical ruling 128 (the scale measurement in millimeters, treated as tenths of an inch). The wing nut is then tightened. Since the distance of the length-graduation 183 from the 0 graduation (indicated in Fig. 2 by the position of L_T and S_T) is the theoretical length of the scale at that length of fish, the points of intersection of the vertical rulings [2] of the paper corresponding to the scale measurements to the several annuli (17, 33.5, 52, . . ., identified in Fig. 2 as S'_1, S'_2, S'_3, . . .) with the ruler will give "corrected" scale measurements (S_1, S_2, S_3, . . . along the ruler)

[2] The horizontal rulings of the cross-section paper play no part in the nomograph. For convenience in reading from the paper, several horizontal rows of figures are added to show the distances of the vertical rulings from the 0 ruling at the right. As an additional aid dark, vertical pencil lines are drawn along the "half-inch" rulings to supplement the heavy lines printed on the paper at intervals of 1 inch.

TABLE 1.—*Original scale measurements and calculated standard lengths at the end of each year of life of two 8-year-old Nebish Lake rock bass*

Year of life	Specimen No. 263		Specimen No. 322	
	Scale measurement (millimeters)	Calculated length (millimeters)	Scale measurement (millimeters)	Calculated length (millimeters)
1	17	45	15	34
2	33.5	72	41	69
3	52	98	75	105
4	64	113	100	128
5	86	139	116	142
6	106	160	138	160
7	116	171	152	171
8	125	180	161	178
8+	128	[1]183	167	[1]183

[1] Length at capture

adjusted to the magnification at which the ruler was prepared. We are not interested, however, in these corrected or normalized measurements but wish rather to know the lengths of fish corresponding to them. These

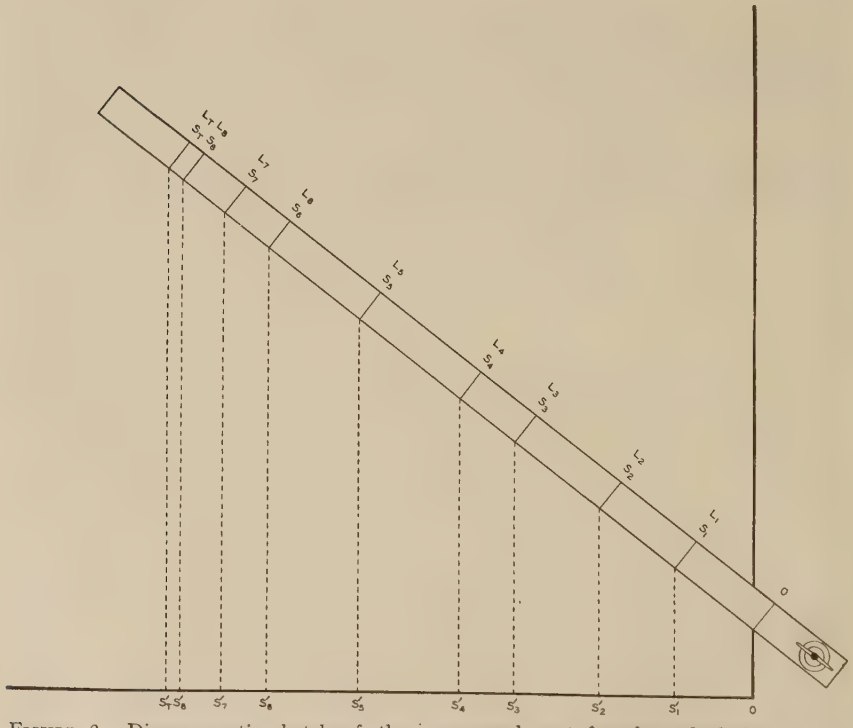

FIGURE 2.—Diagrammatic sketch of the nomograph, set for the calculation of the growth of Specimen No. 263. See text for explanation.

lengths (45, 72, 98, ...) can be read directly from the ruler which was so drawn that the distance of each length graduation (L_1, L_2, L_3, . . .) from 0 is the corresponding theoretical scale length.

Had the scale measurements of Nebish Lake rock bass been marked by pencil on cardboard or paper strips and not recorded as numerical values, the procedure for the nomographic calculation would have been essentially the same except that (1) the vertical rulings would have served only as guide lines and (2) a much smaller nomograph would have had to be constructed. When cardboard strips are employed for the recording of scale measurements, the dimensions of a nomograph of the type described are determined within rather narrow limits by the actual sizes of the magnified scale images. Procedures such as those outlined in the preceding section to obtain a device of convenient proportions could not be followed. (In this connection, the questions may be raised as to whether the advantages of these cardboard strips over an actual numerical recording of scale measurements are as great as is commonly represented.)

The second example (Specimen No. 322) presents the difficulty that the total scale measurement (167 millimeters; 16.7 inches on the nomograph) exceeds 16.23 inches, the distance of the length-graduation 183 from the 0 graduation of the ruler. To meet this difficulty the body-scale ruler is locked in a horizontal position and a steel ruler graduated by tenths of an inch is laid on the paper in such a position that 167 (16.7 inches) is directly above the length-graduation 183. The 0 graduation of both rulers must, of course, be in vertical alignment. The calculated lengths (34, 69, 105, . . .) are then read from the body-scale ruler at points directly below the scale measurements on the steel ruler (15, 41, 75, . . .). Here, the vertical rulings of the paper serve merely as guide lines.

For the Nebish Lake rock bass, Specimen No. 332 represents an extreme condition not frequently encountered. It was included in this account only to emphasize the importance of a careful planning of the proportions of a nomograph. The multiplication of the theoretical scale measurements by the factor 1.15 in the preparation of the body-scale ruler increased the distances of the several graduations from 0 sufficiently that for almost all fish that distance exceeded the original measurement of the scale radius. A larger factor would have eliminated entirely any need for the steel ruler with 0.1-inch graduations, but at the same time, for the computation of the growth of many fish, would have caused the body-scale ruler to be set at a greater angle with the horizontal than would be desirable.

Literature Cited

Carlander, Kenneth D.

1945a. Age, growth, sexual maturity, and population fluctuations of the yellow pike-perch, *Stizostedion vitreum vitreum* (Mitchill), with reference to the commercial fisheries, Lake of the Woods, Minnesota. Trans. Am. Fish. Soc., Vol. 73 (1943), pp. 90–107.

1945b. Growth, length-weight relationship and population fluctuations of the

tullibee, *Leucichthys artedi tullibee* (Richardson), with reference to the commercial fisheries, Lake of the Woods, Minnesota. Trans. Am. Fish. Soc., Vol. 73 (1943) pp. 125–136.

Carlander, Kenneth D., and Lloyd L. Smith, Jr.
1944. Some uses of nomographs in fish growth studies. Copeia, 1944, No. 3, pp. 157–162.

Fry, F. E. J.
1943. A method for the calculation of the growth of fishes from scale measurements. Univ. of Toronto Stud., Biol. Ser., Pub. Ont. Fish. Res. Lab., No. 61, pp. 5–18

Hile, Ralph
1941. Age and growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in Nebish Lake, Wisconsin. Trans. Wis. Acad. Sci., Arts, and Lett., Vol. 33, pp. 189–337.

Monastyrsky, G. N.
1930. Uber Methoden zur Bestimmung des linearen Washstums des Fische nach der Schuppe. Rep. Sci. Inst. Fish Cult., Vol. 5, No. 4, pp. 5–44. [Russian with German summary]

Segerstråle, Curt
1933. Ueber scalimetrische Methoden zur Bestimmung des linearen Wachstums bei Fischen, insbesondere bei *Leuciscus idus* L., *Abramis brama* L., und *Perca fluviatilis* L. Acta Zoolog. Fennica, Vol. 15, pp. 1–168.

Van Oosten, John
1941. The age and growth of fresh-water fishes. *In*: A Symposium on Hydrobiology, Univ. of Wis. Press, pp. 196–205.

FISH-POPULATION AND CATCH DATA FROM MINNESOTA LAKES[1]

JOHN B. MOYLE, JEROME H. KUEHN, AND CHARLES R. BURROWS

Division of Game and Fish, Minnesota Department of Conservation
St. Paul, Minnesota

ABSTRACT

From seining it is concluded that the average game-fish lake of southern Minnesota has a fish population of about 110 pounds per acre of which about one-sixth is made up of large predaceous species. Pike (*Esox lucius*) is the most widespread and, from the viewpoint of fishery management, the most valuable predatory fish in Minnesota waters. Pike is nearly always a co-dominant with largemouth black bass (*Micropterus salmoides*) in "bass-panfish" lakes and with yellow pikeperch (*Stizostedion v. vitreum*) in "walleye" lakes. As a check on populations of yellow perch (*Perca flavescens*) and small centrarchids, pike are probably more effective than either bass or pikeperch. A comparison of the poundage composition of the anglers' take with the poundage composition of the fish population found by seining shows that fishing pressure in Minnesota is much heavier for the large predaceous species than for the panfishes. Pikeperch are subjected to heaviest fishing pressure, with pike second. Rough-fish lakes in southern Minnesota were found by test seining to have an average of about 375 pounds of fish per acre, of which 280 pounds were rough fish, largely carp (*Cyprinus carpio*). An average removal of 97 pounds per acre per season over 25 years has had no permanent effect in reducing the size of carp and buffalo populations in 14 such waters. In general, rough fish appear to have little effect on the total poundage of game fish in southern Minnesota lakes. Rough fish are, however, usually associated with large populations of crappies (*Pomoxis* spp.) and somewhat reduced perch and pike populations.

Gill-net and hoop-net catches and indices are considered. Fishing selectivity of gill nets and the use of poundage data from gill-net catches in judging the relationship between perch and predatory fish are discussed.

INTRODUCTION

Accurate or even reasonably accurate estimates of the size, structure, and utilization of fish populations in large natural lakes are difficult to obtain. Yet such statistics are essential and the acquisition of them must be one of the basic aims of any fishery program. In Minnesota, which has 10,000 lakes of which about a fourth are good fishing waters, the collection and interpretation of such data offer no mean task. In most waters the removal and tallying of an entire fish population, such as has been frequently done in ponds, is impractical. The use of fish poisons and of marking-and-

[1] The writers wish to thank Dr. Raymond E. Johnson, Research Supervisor, and Mr. John Dobie and other members of the Fisheres Research Unit for aid and advice and Dr. Kenneth D. Carlander of Iowa State College, Ames for helpful suggestions.

recovery techniques such as that of Schnabel (1938), are limited to special situations and unusually intensive studies of small bodies of waters. Extensive electric shocking, modified from the method of Haskell (1940), has been carried out on Minnesota streams (Smith, Johnson and Hiner, 1949) but this method is not applicable to lakes.

From the viewpoint of state-wide fishery management the only practical methods now available for sampling fish populations to estimate size, structure, and utilization are those long used by fishermen: seining, gill netting, hoop netting, and angling. As measuring sticks of fish populations all of these methods are subject to much error, but they are the best we have. The principal difficulties encountered are: (1) lack of knowledge as to what constitutes an adequate sample from the statistical viewpoint; (2) limitation from the practical point of view of the amount of sampling that can be done where many lakes must be managed; and (3) insufficient information as to the catching efficiency of different kinds of gear for various species of fish.

The purpose of the present paper is to summarize the large body of data on seining, gill netting, hoop netting, and angling that has been gathered from Minnesota waters and, in the light of this summarization, to evaluate our present knowledge of fish populations in Minnesota in terms of practical fishery management.

Fish Population as Shown by Test Seining

Seining data from 112 Minnesota lakes offer the most reliable evidence of the size and structure of fish populations. These lakes were "test seined" in 1938–1942. Usually seines of 1¼-inch mesh were used and several acres of littoral area in each lake were seined. When these seining data are considered as estimates of total populations of fish, several limitations inherent to seining should be remembered: (1) smaller fish can escape through the meshes; (2) even with greatest care some large fish are often lost; and (3) seining is limited to waters that are fairly shallow (15 feet in these operations) and free from snags. In general, estimates of fish populations from seine hauls are minimal and are certainly representative only of littoral areas. However, since most of the lakes in this series are shallow and are usually more than two-thirds littoral area, it is likely that the seining data give a fair approximation of the real size and structure of the fish populations sampled.

The 112 lakes seined are in the southern half of Minnesota and are mostly of the bass-panfish and rough-fish types. Total populations of fish estimated from these operations ranged from 14.2 to 2,730 pounds per acre with an average for all lakes of 208 pounds per acre of water seined. If this series of lakes is divided into game-fish and rough-fish waters, with 40 pounds of rough fish per acre as a separation point, the average total weight of fish in the rough-fish lakes is 374.7 pounds per acre and that in the game-fish waters 109.1 pounds per acre.

A further break-down of these data into kinds of fish is presented in Table 1. In this table certain species that occupy similar niches in the environment (such as the different species of bullheads) have been lumped together.

In game-fish lakes, judging from hauls in shallow water with ¼-inch-mesh minnow seines, there are usually 20 to 40 pounds of small fish per acre that can be expected to pass through the mesh of 1½-inch-mesh seines.

TABLE 1.—*Pounds of fish per acre (average and range) taken by seine from littoral areas of 112 southern Minnesota lakes*

Species	68 game-fish lakes		44 rough-fish lakes	
	Mean	Range	Mean	Range
Pike	6.9	0.0– 42.5	3.7	0.0– 29.2
Yellow pikeperch	3.0	0.0– 54.5	2.2	0.0– 21.1
Bass[1]	6.9	0.0– 30.5	6.3	0.0– 66.5
Crappies[2]	25.0	0.0–273.3	34.8	0.0– 643.0
Yellow perch	19.2	0.0–184.0	3.9	0.0– 111.6
Sunfishes[3]	25.7	0.0–178.2	25.0	0.0– 462.4
Rock bass	0.5	0.0– 8.5	.....	0.0– 0.2
Bullheads	9.0	0.0–144.2	13.7	0.0– 133.6
White suckers	4.9	0.0–102.3	4.3	0.0– 91.0
Carp	6.9	0.0– 35.2	198.0	40.5–2,222.0
Buffalo[4]	0.3	0.0– 11.9	75.7	0.0–1,144.0
Sheepshead	0.6	0.0– 14.5	4.8	0.0– 122.0
Others[5]	0.8	0.0– 16.7	2.8	0.0– 57.0
All species combined	109.7	14.2–444.6	374.7	63.5–2,730.0

[1] Mostly largemouth black bass (*Micropterus salmoides*)
[2] Mostly black crappies (*Pomoxis nigro-maculatus*)
[3] Mostly bluegills (*Lepomis macrochirus*) and pumkinseeds (*L. gibbosus*)
[4] Mostly bigmouth buffalo (*Megastomatobus cyprinella*)
[5] Mostly northern redhorse (*Moxostoma aureolum*), shortnose gar (*Lepisosteus platostomus*), and bowfin (*Amia calva*) in bass-panfish lakes and quillback (*Carpiodes cyprinus*) and shortnose gar in rough-fish lakes

On the average, the larger predaceous fishes (black bass, yellow pikeperch, and pike) made up about 15.3 percent of the total poundage taken from game-fish waters and about 3.5 percent in rough-fish waters. The difference when considered in terms of pounds per acre is less marked—an average of 16.8 pounds per acre of larger predaceous fishes in game-fish waters and 12.2 pounds per acre in rough-fish waters.

Table 1 shows that large populations of crappies often are found in rough-fish lakes (a fact well known to commercial fishermen operating on such waters) and that yellow perch and pike are less abundant in rough-fish lakes than in game-fish waters. It will be noted also that although game-fish and forage-fish populations are somewhat lower in rough-fish than in game-fish waters, yet, for the most part, the rough fish seem to be occupying a niche in the environment not occupied or not present in non-rough-fish waters. The average weight of game and forage fish is 101.1 pounds per acre in the gamefish lakes and 93.4 pounds in rough-fish lakes. The difference of about 8 pounds, is much more than compensated by the additional 281 pounds per acre of carp, buffalo, and other rough fish in the rough-fish waters.

All kinds of fish were not taken from all lakes and a somewhat different, although generally similar, picture is presented when the average number of pounds per acre of each kind of fish is calculated on the basis of *only those lakes from which the particular kind of fish was taken* (Table 2). This compilation is most useful for comparing with gill-net and hoop-net indices (to be discussed later) which are also calculated on this same basis.

TABLE 2.—*Average pounds of fish per acre taken by seine from littoral areas of 112 southern Minnesota lakes as calculated on the basis of the number of lakes from which a particular kind of fish was taken*

Species[1]	Number of game-fish lakes	Pounds per acre	Number of rough-fish lakes	Pounds per acre
Pike	59	8.0	30	5.4
Yellow pikeperch	25	8.1	14	7.0
Bass	55	8.5	29	9.6
Crappies	60	28.3	34	45.0
Yellow perch	41	32.1	21	8.1
Sunfishes	63	29.7	34	32.4
Rock bass	16	2.2	0	0.0
Bullheads	41	14.7	34	17.7
White suckers	34	9.8	23	7.9
Carp	36	11.0	43	202.6
Buffalo	4	4.3	20	166.6
Sheepshead	9	5.0	13	16.1
Others	15	4.0	16	7.6

[1] Certain species combined as in Table 1

A shared dominance among the three large predaceous fishes, pike, yellow pikeperch, and largemouth black bass, similar to that which might be assumed from Table 1 for the "average" lake of the game-fish series, is not the usual situation. Generally, dominance is shared by two species: pike and yellow pikeperch or pike and largemouth black bass. These combinations are characteristic of "bass-panfish" and "pike" (that is pikeperch or "walleye") lakes of Eddy (1938). In the series of 68 game-fish lakes, pikeperch were taken from 25, bass from 55, and pike from 59. The "triple-predator combination" of pike-bass-pikeperch was noted in only 19 lakes while the bass-pike combination was taken in 49 lakes. In only 2 lakes in the series were pike and pikeperch and no black bass taken. These results may be due partly to the inability of seines to take pikeperch in deep waters, but the fishing history of these waters supports the conclusion that most of the lakes in this series are of the "bass-panfish" type in which pike and black bass are the normal predators It might be noted that many of these lakes have had a long history of stocking with pikeperch fry that has failed to establish this species in any appreciable numbers.

In 49 lakes where pike and black bass were the large predatory fishes, the ratio between the poundages of these two species as determined by seining, ranged from 1:30.9 to 1:0.02 with a median ratio of 1:0.64. However, since the average weight of pike taken by seining was 1.12 pounds and

that of black bass was 0.76 pound, it appears that on the basis of numbers of fish the two species are often about equally abundant. Since pike are known to be more cannabilistic in rearing ponds than are black bass, it is likely that pike are the primary predator in most "bass-panfish" lakes and that the predatory role of bass in such waters is secondary and not comparable to its role as primary predator in ponds where only black bass and bluegills are present.[2]

It has already been noted that on the average 15.3 percent of the poundage of fish in the game-fish lakes was of the larger predatory species. This value is considerably lower than the 26 percent of black bass, by weight, found by Swingle and Smith (1941) in southern ponds. It may well be that dual- and triple-predator combinations are less efficient in terms of poundage of predaceous fish produced than are black bass in ponds, but it should also be pointed out that the multiple-predator combinations are probably more efficient in keeping populations of small fishes, such as yellow perch and sunfishes, under control than are black bass alone.

Fish Populations as Shown by Seining for Rough Fish

Removal of rough fish from lakes by means of seines hauled under the ice has been practiced regularly in southern Minnesota for 25 years. The seines operated by commercial fishermen or State-employed crews usually have been 2,400 to 4,000 feet long, 12 to 20 feet deep, and with a mesh of 1½ to 2½ inches, bar measure. Fourteen lakes have been selected on the basis of almost complete records of seining in a number of consecutive years.[3] These lakes are surrounded by fertile farm land. Their sizes range from 227 to 3,808 acres and their depths are largely less than 15 feet. Seining records from 14 lakes vary as to completeness, but 10 of the 14 have been seined 20 or more years during the past 25 years.

The average harvest of rough-fish from the individual lakes in this series ranges from 36.7 to 189.8 pounds per acre for each seining season. The grand average yield for all 14 lakes has been 96.9 pounds of rough fish per seining season. When the data on removal of rough fish from those lakes with most nearly complete records are tabulated by fishing seasons (Table 3), no trends, either toward increase or decrease in catch are evident. It appears that differences in the catch in consecutive years reflect such variables as fishing pressure, weather, and the price of fish rather than the actual size of the rough-fish populations in the lakes. Since there is no general downward trend in the catch, it is evident that for the years considered the annual poundage growth of rough-fish populations in these waters has been at least as great as the average poundage removed.

---

[2] The average yield of fingerlings from 12 pike ponds operated in 1948 was 12.7 pounds per acre. Comparable earlier figures for yellow pikeperch and largemouth black bass are, respectively, 48.4 and 80.5 pounds per acre (Smith and Moyle, 1945).

[3] These lakes are: Buffalo, Hall, Bright, North Silver, and South Silver in Martin County; Gorman, Horseshoe, Sabre, Upper Sakatah, Lower Sakatah, and Scotch in Le Sueur County; Byllesby in Dakota County; Elysian in Waseca County; and Shetek in Murray County. Harvest is calculated by dividing the total catch by the total acreage.

A comparison of the average yearly harvest from these 14 lakes (96.6 pounds per acre) with the average standing crop of rough fish found by test seining of 40 rough-fish lakes (281 pounds per acre for the area seined) suggests that the annual poundage increment of rough fish in southern Minnesota waters is perhaps one-third of the standing rough-fish crop.

TABLE 3.—*Pounds of rough fish removed per acre per seining season from five Minnesota lakes*

[Calculated on the basis of entire area of lake]

Seining season	Buffalo Lake	Bright Lake	Sabre Lake	South Silver Lake	Upper Sakatah Lake
1947–48	283	27	...	136	68
1946–47	44	105	116	62	119
1945–46	48	108	97	118	34
1944–45	268	49	90	51	138
1943–44	82	67	15	75	66
1942–43	...	47	273	257	44
1941–42	181	70	11	209	58
1940–41	...	...	...	37	15
1939–40	...	...	...	...	154
1938–39	77	4	113	74	159
1937–38	149	...	205	192	...
1936–37	29	1	436	160	5
1935–36	13	136	...	421	...
1934–35	191	177	431	225	39
1933–34	189	...	59	81	58
1932–33	91	35	238	109	182
1931–32	81	60	129	341	45
1930–31	114	72	104	...	147
1929–30	105	102	185	172	7
1928–29	570	89	141	545	285
1927–28	280	5	180	447	111
1926–27	53	56	390	398	24
1925–26	211	118	39	79	4
1924–25	314	35	163	106	...
1923–24	252	9	5	66	6

THE ANGLERS' CATCH

Summer angling makes up the bulk of Minnesota fishing. In an attempt to evaluate this sport fishery, a state-wide, "spot" creel census was carried out in Minnesota during the years 1939–1942 (Hiner, 1943). The summer phase of this census covered 226 lakes from which 121,774 fish were tallied and on which 24,312 fishermen were recorded as fishing 73,123 man-hours. Fish were taken at the average rate of 1.67 fish per man-hour.

The percentage composition of the total catch tallied, in terms of both numbers and calculated weight, is given in Table 4. The estimated weights in pounds of fish kept by anglers and used in converting numbers to pounds are: pike 2.0; yellow pikeperch 1.7; crappies 0.5; sunfish 0.25; bullheads 0.25; yellow perch 0.25; and black bass 1.0.

Included also in Table 4 is the proportion of the 226 lakes from which each kind of fish was tallied during the census.

It will be noted that 62 percent of the catch in terms of calculated weight was made up of the large predaceous fish, pike, yellow pikeperch, and

black bass. Since these same species comprised only about 15 percent of the weight in the game-fish lakes seined it is apparent that the larger predaceous fish are subject to much heavier fishing pressure than are other fishes in Minnesota waters.

If the figures for the weight of the population of the different kinds of fish in lakes from which they were taken by seining (Table 2) are com-

TABLE 4.—*Percentage composition of anglers' catch and percentage of lakes from which each species was tallied as shown by "spot" creel census of 226 Minnesota lakes*

Species	Percentage of total number	Percentage of total weight	Percentage of lakes in which tallied
Pike	6.0	19.0	78.0
Yellow pikeperch	10.7	28.8	51.1
Black bass	2.4	3.8	53.8
Yellow perch	4.0	1.6	51.4
Crappies	24.7	19.5	72.1
Sunfishes	42.9	17.0	61.8
Bullheads	6.9	2.7	42.2
Others	2.4	7.6	47.1

pared with the percentage of lakes from which each species was tallied in the creel census (Table 4), it is apparent that on a weight basis (pounds removed *versus* pounds present) that in Minnesota fishing pressure is greater for pikeperch than for any other lake fish and that pike rank second in this respect. Following in descending order are sunfishes, black bass, and crappies (these three apparently subject to about equal fishing pressure) and bullheads and perch (for which fishing pressure is very light).

Concerning the mortality of yellow pikeperch, Eddy (1940) stated that, "tagging studies of wall-eyed pike carried on in several Minnesota lakes by U. S. Forest Service and the University, show that about 12 percent of the three- and four-year-old fish die a natural death each year and that from 6 to 25 percent of these age classes are caught annually by fishermen."

Although the yellow pikeperch usually is considered to be the most important game fish in Minnesota waters, the importance of pike in pikeperch waters should not be overlooked. According to unpublished data on a creel census of Lake Winnibigoshish, Cass and Itasca Counties, carried out by Jerome Stoudt in 1939, the catches of pike and pikeperch were respectively 1.24 and 0.90 pounds of fish per man-hour of angling. This lake is one of the best pikeperch lakes in Minnesota.

It is plain that in Minnesota lakes a larger harvest of fish could be had if fishing pressure were greater for the smaller fishes, especially for sunfishes, crappies, yellow perch, and bullheads. Of all the common species, yellow pikeperch and pike are most in need of careful management.

GILL NETTING AND GILL-NET INDICES

Gill nets have been used in Minnesota lake-inventory work since 1936, because the nature of the basins of many lakes makes seining impossible.

Originally tullibee nets, usually of 1½-inch mesh, bar measure, were used, but since 1941 nearly all netting has been done with standard "experimental" nets. These nets are 250 feet long by 6 feet deep and are made up of five 50-foot sections of webbing the meshes of which (bar measure, inches) are ¾, 1, 1¼, 1½, and 2.

All gill nets are set overnight and are considered to be 24-hour sets, although in practice the time they are in the lake may range from 20 to 30 hours. It is likely according to the work of Van Oosten, Hile, and Jobes (1946) on netting in the Great Lakes that such small differences in time have but little effect on the catch.

In most Minnesota lake reconnaissance the number of gill-net sets made has been determined by the size of the lake. The following scheme for allotting sets has been used: 100 acres or less—8 sets; 100 to 300 acres—12 sets; 300 to 500 acres—15 sets; 500 to 1,000 acres—20 sets; 1,000 to 5,000 acres—5 sets for each 1,000 acres above the 20 sets for the first 1,000.

Gill-net sets are distributed throughout the lake with a view toward sampling all areas and obtaining a general picture of the fish population in the whole lake. Usually the nets are set from shore outward toward the center of the lake. Perhaps a better approach for large lakes is that of Miller and Kennedy (1948) who grouped gill-net catches from Great Bear Lake by "localities" and calculated catch on this basis rather than calculating a general average catch for the whole lake.

Gill-net catches have been expressed as the number or pounds of fish taken per 100 feet of experimental net in one day; that is, the catch of a 250-foot net divided by 2.5. Several terms have been applied to this unit of catch, including "gill-net ratio," "gill-net factor" and "gill-net index." The latter term appears to be most descriptive and is therefore used here.

Prior to 1947 all gill-net catches from Minnesota waters were recorded as numbers of fish only but in 1947 and 1948 catches were recorded both as numbers and weight of fish. When a considerable mass of such data was accumulated average gill-net indices for commoner species of fish were calculated. These averages were based on catch data from those lakes from which a particular kind of fish was taken. This seems to be the best way of handling the data since it is known that certain kinds of lakes favor certain kinds of fish and a species of fish must be assumed to be absent from a water until its presence is proven.

Gill-net indices in terms of numbers for some of the commoner kinds are given in Table 5. This table includes data from all lakes netted in the period 1941 to 1947. Unfortunately, it was impossible during the war to obtain new experimental netting and the averages in Table 5 are influenced to an unknown degree by the smaller catches of nets in poor repair. In 1948 only new nets in good condition were used. Catch data from 84 lakes netted in the summer of that year are shown in Table 6. These gill-net indices for 1948 are in terms of both numbers and weights of fish.

TABLE 5.—*Average gill-net indices as determined from the catches of experimental nets fished in 156 lakes (1941–1947) and expressed as numbers of fish caught per 100 feet of gill net in 24 hours*

[Averages based on only the lakes from which a particular kind of fish was taken. See text for specifications of the experimental gill nets]

Species	Number of fish
Pike	1.65
Yellow pikeperch	1.62
Black bass	0.58
Crappies	2.01
Yellow perch	10.80
Sunfishes	1.51
Bullheads	5.68
White suckers[1]	1.59
Rock bass[2]	1.05

[1] *Catostomus commersonnii*
[2] *Ambloplites rupestris*

TABLE 6.—*Gill-net indices for 84 Minnesota lakes sampled in the summer of 1948 expressed both as numbers and pounds of fish per standard set*

[See text for specifications of the experimental gill nets]

Species	Number of lakes	Gill-net index (by number)		Gill-net index (by weight)	
		Mean	Maximum	Mean	Maximum
Pike	71	1.56	7.79	3.46	14.86
Yellow pikeperch	52	2.05	6.68	2.30	9.01
Black bass	41	0.55	3.07	0.26	0.99
Crappies	61	2.82	23.52	0.76	4.42
Yellow perch	81	13.92	228.24	3.05	78.33
Sunfishes	62	4.62	22.39	0.91	6.47
Bullheads	63	4.29	42.71	3.69	92.81
White suckers	66	0.96	9.77	1.15	10.90
Rock bass	30	1.03	8.06	0.42	3.68

HOOP NETTING AND HOOP-NET INDICES

Hoop nets, like gill nets, are selective fishing gear, and their catch in Minnesota has also been evaluated on a comparative basis by means of state-wide, average indices.. The hoop nets used have 1-inch mesh (bar measure), and hoops 30 inches in diameter. They are set in pairs connected at the throat with 15-foot leads. The hoop-net index is defined as the catch in pounds per pot in 24 hours. The standard set is 24 hours.

Hoop netting as a sampling method in Minnesota waters began with the necessity for determining which lakes in northern Minnesota contained enough bullheads to warrant removal by extensive hoop-netting operations. Through 1947, 119 lakes suspected of having large populations of bullheads were test netted. The average catches of the more common kinds of fish taken from these lakes are shown in Table 7. Experience with these waters shows that if a lake has a hoop-net index for bullheads of more than 20 pounds per pot in 24 hours, bullheads are abundant enough to warrant commercial fishing.

TABLE 7.—*Averages and ranges of hoop-net indices from 119 Minnesota lakes suspected of having large populations of bullheads*

[Averages based on only the lakes from which a particular kind of fish was taken]

Species	Pounds per pot in 24 hours[1]	
	Mean	Maximum
Pike	0.16	0.96
Yellow pikeperch	0.23	0.89
Black bass	0.66	1.22
Crappies	0.07	0.44
Yellow perch	0.31	5.45
Sunfishes	0.24	1.75
Bullheads	39.10	577.77
White suckers	0.56	0.90
Rock bass	0.15	4.40

[1] Poundage of fish other than bullheads is calculated from average length-weight relationships because game fishes were not weighed (to minimize handling losses). Bullheads, weighed after dressing, were assumed to be one-half the round weight

In 1947, hoop-net catches were made in 46 lakes as part of the lake-survey program, and in 1948, 66 lakes were netted. The hoop-net indices for these two seasons are shown in Table 8.

TABLE 8.—*Hoop-net indices (expressed as pounds per pot for 24 hours of fishing) in 112 Minnesota lakes surveyed in 1947 and 1948*

[Averages based on only those lakes from which a particular kind of fish was taken]

Species	1947 (46 lakes)		1948 (66 lakes)	
	Mean	Maximum	Mean	Maximum
Pike	0.73	6.82	0.33	1.83
Yellow pikeperch	0.20	1.31	0.22	1.04
Black bass	0.37	0.49	0.40	3.99
Crappies	0.30	0.69	0.15	1.07
Yellow perch	0.19	1.26	0.37	4.60
Sunfishes	0.72	27.82	0.81	4.68
Bullheads	4.56	97.00	4.79	33.08
White suckers	0.33	1.54	0.50	1.93
Rock bass	0.89	4.18	0.36	1.89

SELECTIVITY OF GILL NETS

Gill nets are passive fishing gear. Their catch depends upon the movements of the fish themselves. As a result, the more active fishes, especially those with a large cruising and feeding range, are likely to be most easily caught. Other factors that influence the catchability of fish in gill nets are: (1) the occurrence of appurtenances such as spines, which can become entangled in the meshes; (2) the size of mesh in the net; and (3) season of the year and even the time of day. Carlander and Cleary (1949) found in Lake of the Woods that yellow perch were more likely to be taken in gill nets during the day and saugers and pikeperch at night. Larger voracious species such as pike may also be "baited" into the nets by previous catches of small fish such as perch.

Although the selectivity of gill nets is generally recognized, there is little published information on this thorny problem. The reason is obvious; sources of error are so many that exact answers can hardly be hoped for. It is possible, however, to gain a general idea of the catching efficiency of experimental gill nets in Minnesota lakes by comparing gill-net indices based on weight with seining data on the average number of pounds per acre from those lakes from which a particular kind of fish was taken (Tables 2 and 6).

These averages are not from the same series of lakes, but even if considerable allowance is made for this defect of the data, it is apparent that pike, yellow pikeperch, and bullheads are much more easily taken in gill nets than the other fishes listed.

Experimental gill nets appear to have a moderate catching efficiency for perch and suckers with a low efficiency for black bass, crappies, sunfish, carp, and other large rough fish.

It should be emphasized that the selectivity of gill nets is greatly influenced by the size of mesh in the nets. On the upper Mississippi River, where gill nets with mesh of 7 inches stretch measure, are used in the commercial fishery, these nets have a "high efficiency" for carp and buffalo but pikeperch and pike are "rarely caught in appreciable numbers" and crappies, bluegills, gars, suckers, bullheads, and perch are "never or almost never caught," (Upper Miss. Riv. Cons. Comm., 1946, p. 7).

When it is considered that there is an unknown and probably large sampling error in the way gill nets catch fish and that the selectivity of gill nets is poorly understood, it is apparent that gill-net catches can be considered measures of the size of fish populations only in a very general sense. Gill-net catches can be of rough quantitative value, especially when used comparatively, but the limitations of gill netting should be understood.

Gill-Net Catches and Perch Problems

The control of excessive numbers of yellow perch is a frequent fishery-management problem in Minnesota lakes, especially in pikeperch waters. Here, perch are little fished and are often considered a "weed" fish. Since the most practical way of controlling perch populations is through increased production of predatory fish, the question arises as to the size of a predatory fish population large enough to hold the perch in check.

In most pikeperch waters the size and structure of the fish population cannot be estimated by direct methods. The problem has been approached by the use of gill-net catches expressed in weight. Of course, such catches cannot be interpreted as showing the weight structure of the fish population; they show only the weight structure of the catch.

Weight relationships of yellow perch, yellow pikeperch, and pike from 24 lakes netted in the summers of 1947 and 1948 are first considered. These lakes are grouped per set of a standard experimental gill-net; (1) 9 lakes with a "high" perch catch in which the average catch for this species was

51 percent of the total catch by weight (range for individual lakes, 28 to 94 percent): (2) 10 lakes with a "moderate" catch of perch in which that species made up on the average 14.9 percent of the total catch by weight (range, 2 to 33 percent); and (3) 5 lakes with a "low" perch catch in which perch averaged 2.5 percent of the total catch by weight (range, 1 to 4 percent).

In the 9 lakes with a "high" catch of perch (51 percent of total catch by weight), on the average, pike and pikeperch combined made up 29 percent of the total catch. Of this amount pike was 15 percent (range, 2 to 33 percent) and pike perch 14 percent (range, 2 to 22 percent).

In the 10 lakes with a "moderate" catch of perch (average 14.9 percent) the average combined weight of pike and pikeperch was 51 percent of the total poundage. Of this average, pike comprised 30 percent (range, 22 to 57 percent) and pikeperch 21 percent (range, 4 to 43 percent).

In the five lakes with a "low" catch of perch (average 2.5 percent), pike and pikeperch made up 41 percent of the total catch by weight with pike averaging 11 percent (range, 4 to 34 percent) and pikeperch 30 percent (range, 7 to 59 percent).

In another series of 12 lakes, pike and yellow perch were caught but yellow pikeperch were not taken. Three of these lakes had "high" perch catches. In them, on the average, perch made up 65 percent of the total catch by weight (range, 47 to 79 percent) and pike average 11 percent of the total catch (range, 2 to 18 percent). Six lakes of this series had a "moderate" perch catch, average, 15 percent of the total catch by weight; range, 4 to 24 percent). Here pike made up 45 percent of the total catch by weight (range 27 to 64 percent). Two lakes had "low" perch catches and averaged 0.6 percent of the total catch by weight. In them pike made up 60 percent of the total catch by weight.

In both series of lakes it will be observed that high catches of yellow perch are associated with low catches of predatory fish. Because other species of fish in the population are not considered, and because of uncertainties in gill netting already considered, exact conclusions concerning the interrelationships in populations containing pike, yellow perch and yellow pikeperch cannot be drawn. However, it does appear from gill-net catches by weight that there is not likely to be an overabundance of perch in a lake if (1) the combined catch of pike and pikeperch exceeds 40 percent of the total gill-net catch by weight or (2) if the catch of pike alone is 20 to 30 percent or more of the total gill-net catch by weight.

Literature Cited

Carlander, Kenneth D., and Robert E. Cleary
1949. The daily activity patterns of some freshwater fishes. Am. Midl. Nat., Vol. 41, No. 2, pp. 447–452.

Eddy, Samuel
1938. Classification of Minnesota lakes for fish propagation. Prog. Fish.-Cult., No. 41, pp. 9–13.

1940. Minnesota lake surveys and fish management. Proc. Minn. Acad. Sci., Vol. 8, pp. 9–14.

HASKELL, DAVID C.
1940. An electrical method of collecting fish. Trans. Am. Fish. Soc., Vol. 69 (1939), pp. 210–215.

HINER, LAURENCE E.
1943. A creel census of Minnesota lakes, 1938–1942. Minn. Dept. Cons., Fish. Res. Inv. Rept., No. 44, 20 pp. [mimeographed]

MILLER, R. B., and W. A. KENNEDY
1948. Observations on the lake trout of Great Bear Lake. Jour. Fish. Res. Bd. Can., Vol. 7, No. 4, pp. 176–189.

SCHNABEL, ZOE EMILY
1938. The estimation of fish population of a lake. Am. Math. Monthly, Vol. 45, No. 6, pp. 348–352.

SMITH, LLOYD L., JR., RAYMOND E. JOHNSON, and LAURENCE HINER
1949. Fish populations in Minnesota trout streams, as determined by the electrical shocking method. Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 204–214.

SMITH, LLOYD L., JR., and JOHN B. MOYLE
1945. Factors influencing production of yellow pikeperch, *Stizostedium vitreum vitreum,* in Minnesota rearing ponds. Trans. Am. Fish. Soc., Vol. 73 (1943), pp. 243–261.

SWINGLE, H. S., and E. V. SMITH
1941. Experiments on the stocking of fish ponds. Trans. 5th N. Am. Wildlife Conf., pp. 267–276.

UPPER MISSISSIPPI RIVER CONSERVATION COMMITTEE
1946. Second Progress Report of the Technical Committee for Fisheries. 27 pp. [mimeographed]. *In*: Proc. of Second Ann. Meeting Upper Mississippi River Conservation Committee; St. Louis, Missouri, Jan. 28, 1946.

VAN OOSTEN, JOHN, RALPH HILE, and FRANK W. JOBES
1946. The whitefish fishery of Lakes Huron and Michigan with special reference to the deep-trap-net fishery. Fishery Bull. Fish and Wildlife Service, Vol. 50, pp. 295–394.

THE AMERICAN SMELT, *OSMERUS MORDAX* (MITCHILL), OF SOUTH BAY, MANITOULIN ISLAND, LAKE HURON

N. S. Baldwin

Ontario Department of Lands and Forests
Toronto, Ontario

Abstract

A smelt fishery established on the streams and freshets flowing into South Bay during the 1948 spawning run yielded a total of 51,382 pounds to local fishermen using dip-nets and seines. The smelt taken averaged 5.7 inches (145 millimeters) in fork length and 0.73 ounce (20.6 grams) in weight. Age-group II comprised 54 percent of the catch and age-groups III and IV 38 and 8 percent, respectively. Age-group II averaged 5.4 inches in length, age-group III 6.1 inches and age-group IV 7.2 inches. The estimated egg content in five fish ranged from 9,650 to 27,600 and was not entirely dependent on size. Some general observations on the food and spawning behavior of the smelt are also presented and comparisons with other populations made.

Introduction

The American smelt, after its spectacular dispersal from Crystal Lake, Michigan, where it was introduced in 1912, (Van Oosten, 1937; Dymond, 1944), appears to be well established in the Great Lakes. Although smelt are believed to be very abundant in the Canadian waters of the Great Lakes, an intense, well organized fishery has not been developed and potential production is still unknown.

In 1947 the Ontario Department of Lands and Forests commenced an experimental fishery at South Bay, Manitoulin Island, Lake Huron, with the intention of following for a number of years changes in fish populations during intensive fishing of both commercially valuable and undesirable species. The smelt, which had again become abundant after the heavy mortality in the winter of 1942–1943 (Van Oosten, 1947), were considered a possible factor influencing the production of lake trout (*Cristivomer namaycush*) and lake whitefish (*Coregonus clupeaformis*) in the bay. In the spring of 1948, therefore, a fishery was organized to take as many spawning smelt as possible from the streams and freshets flowing into South Bay.

South Bay extends 18 miles into the southern part of Manitoulin Island and connects with Lake Huron through a narrow channel about 300 yards wide and 5 fathoms deep (Fig. 1). The bay, which varies from 1 to 2 miles in width, has an upper basin with a maximum depth of 40 fathoms and a shallower lower basin with a maximum depth of 10 fathoms. Al-

most all the streams enter the bay at the upper basin, and it was from these waters that the smelt were taken. An exchange of smelt could take place between South Bay and Lake Huron through the shallow lower basin and channel but it is not believed to be great.

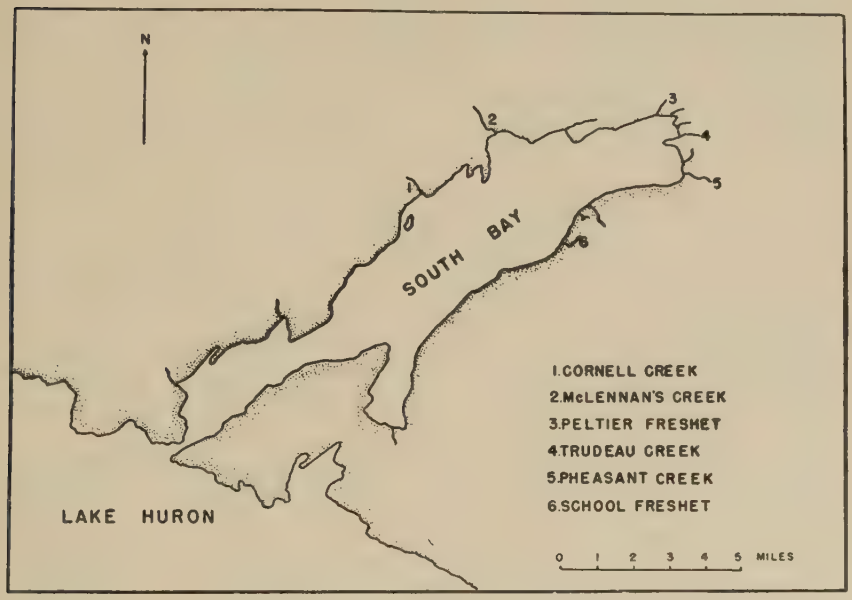

FIGURE 1.—Map of South Bay and vicinity.

THE SPAWNING RUN

Smelt of the 1948 spawning run were first observed in the streams on the night of April 10. On April 14, the day after the ice had broken on the bay, the first heavy runs occurred in two of the larger streams. On that night, 1,575 pounds of smelt were taken from one stream by means of three dip-nets and a 20-foot seine, the gear in general use during the run. Within 5 days runs were reported in the majority of streams flowing into South Bay. The runs in general began first in the larger streams. Smelt did not enter one small, cold freshet until April 23.

The spawning habits of the South Bay smelt were similar to those of smelt in Michigan (Langlois, 1935), (Creaser, 1926), and in New Hampshire (Hoover, 1936). Entry into the streams was made after sundown with the smelt generally drifting back to the bay before or at daybreak. In the more heavily shaded streams, however, some fish remained in sheltered sections throughout the day. At one time schools of smelt were ob-

served at midday in shallow water about 200 feet out from a stream mouth.

Smelt rarely ascended the streams more than a quarter of a mile and usually stopped at the first falls having a drop of over 1 foot.

During the early part of the run male fish predominated and often comprised 90 percent of the night's catch. Female smelt became more plentiful in the catch as the run continued but did not equal males in number until the last 3 or 4 days of the run.

A total of 51,382 pounds of smelt was removed from seven streams and six freshets in the period between April 14 and 27. The catch per acre, based on the area of South Bay, was 2.2 pounds.

TABLE 1.—*Catches of smelt in six South Bay streams, 1948*

Water	Flow (Cubic feet per second)	Period of run	Pounds removed
MacLennan's Creek	35	April 14–23	12,764
Peltier Freshet	4	do. 15–25	11,213
School Freshet	3	do. 17–25	9,405
Cornell Creek	5	do. 19–27	7,978
Pheasant Creek	14	do. 14–24	3,615
Trudeau Creek	66	do. 15–24	1,873

The catch of smelt in the six most productive streams and freshets is summarized in Table 1. The take was greater and the runs appeared heavier in streams with rapid current at their mouths. In spite of their small size, Peltier and School Freshets yielded greater catches than did the larger permanent streams such as Trudeau and Pheasant Creeks. The two freshets had rapid current at their mouths whereas the two permanent streams were sluggish in their lower stretches. Although it is inferred that smelt entered the fast flowing streams in the greater numbers, it is possible that fish in these streams were more concentrated and therefore more readily captured.

Analysis of the Catch

The average length of the smelt taken during the spawning run was 5.7 inches or 145 millimeters (measured to the fork of tail) and the average weight was 0.73 ounce or 20.6 grams. Male fish, which formed 69 percent of the total catch, averaged 5.6 inches and females 5.8 inches. The difference in average length was due largely to an average difference of 0.4 inch between sexes of age group III.

The smelt population appeared to be homogeneous in the upper basin of South Bay, as no consistent size differences in the catch could be detected between streams. The average lengths of the smelt from the several streams ranged from 5.6 to 5.7 inches, and the mean weights varied from 0.67 to 0.74 ounce. Smelt as large as 10.5 inches and as small as 4.5 inches were taken.

The age composition of the 1948 spring catch of smelt is given in Table 2 which includes for comparison the ages of the 1947 summer catch from South Bay and the composition of exploited populations of landlocked fish in Lake Champlain (Greene, 1930) and of anadramous smelt in Great Bay, New Hampshire, (Warfel *et al.*, 1943). Since the smelt collected from South Bay in 1947 were caught by the teeth in large-mesh gill nets, it is believed that the sample was relatively free from size selection with the exception of age-group I. This group formed only 13 percent of the 1947 summer catch and was not present at all in the 1948 spawning run. The age composition of the 1948 sample is believed to be representative of the unexploited population of mature smelt in South Bay.

TABLE 2.—*Age composition (I group excluded) and average lengths of the age groups in four samples of smelt*

[The samples from South Bay in 1948 and 1947 contained 218 and 170 fish, respectively]

Age group	South Bay, 1948 (spring catch)		South Bay, 1947 (summer catch)		Great Bay, 1942 (spring catch)		Lake Champlain[2], 1929 (winter catch)	
	Percentage of total	Average length (inches)	Percentage of total	Average length (inches)	Percentage of total	Average length (inches)	Percentage of total	Average length (inches)
II	54	5.4	50	5.9	68	5.9	64	9.4
III	38	6.1	39	6.7	31	6.7	24	10.6
IV	8	7.2	10	7.6	1	8.7	11	11.4
V	..	...	1	...	..	...	1	11.6

[1] Lengths of the South Bay fish were measured to the fork of the tail; other measurements appearing in the table were taken to the tip of the tail.
[2] After excluding age groups 0 and I (see text)

The growth of smelt in South Bay closely approached that of the anadramous population of Great Bay, New Hampshire (Warfel *et al.*, 1943), but appeared to be slower than that of smelt in Crystal Lake (Beckman, 1942) from which the species spread (Table 2). In Crystal Lake II-group smelt averaged 7 inches, the III-group 7¾ inches, and the IV-group 8¼ inches. The average length of age groups from the "fast-growing race" of Lake Champlain smelt (Greene, 1930), also shown in Table 2, were far above the corresponding lengths for South Bay fish. The Lake Champlain sample contained age-groups 0 to V; age-groups 0 and I which formed 47 percent of this sample are excluded from Table 2 to facilitate comparisons.

Estimates were made of the number of eggs carried by five gravid female smelt from South Bay. A 5.5-inch smelt contained 9,650 eggs; a 6.3 fish 16,200, a 7.0-inch fish 27,600, a 7.5-inch fish 26,800, and an 8.8-inch fish 22,600 eggs.

FOOD

During the summer of 1947 stomachs of about 300 smelt were examined. Although many of these stomachs were classed as empty, inspection was not precise enough to detect food present only in small amounts. Of 56

smelt that contained appreciable quantities of food, *Mysis relicta* occurred in 86 percent, dipterous pupae in 12 percent, and sculpins (Cottidae) in 9 percent. Several stomachs contained mayfly nymphs, caddis larvae, and ostracods.

In the spring of 1948 the viscera of 103 spawning smelt were examined. The alimentary tracts of 65 percent were empty throughout. The lower alimentary tracts of 19 percent contained unidentified material. The stomachs of 13 percent contained mayfly nymphs, 2 percent contained plankton and 1 percent contained spawn.

The moderate feeding of the South Bay smelt when spawning differed from Crystal Lake fish (Creaser, 1926). During the summer while the South Bay smelt are in deep water the food was similar to that reported for fish of Lake Michigan and Crystal Lake (Creaser, 1929) where *Mysis* and *Pontoporeia* formed the main items. Since no winter samples have been taken in South Bay, feeding at that time cannot be compared with that of smelt taken at Crystal Lake in February (Beckman, 1942) which showed a highly piscivorous diet.

Literature Cited

Beckman, William C.
1942. Length-weight relationship, age, sex-ratio and food habits of the smelt (*Osmerus mordax*) from Crystal Lake, Benzie County, Michigan. Copeia, 1942, No. 2, pp. 120–124.

Creaser, Charles W.
1926. The establishment of the Atlantic smelt in the upper waters of the Great Lakes. Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 5 (1925), pp. 405–423.
1929. The smelt in Lake Michigan. Science, 1929, Vol. 69, No. 1798, p. 623.

Dymond, J. R.
1944. Spread of the smelt (*Osmerus mordax*) in the Canadian waters of the Great Lakes. Can. Field-Nat., Vol. 58, No. 1, pp. 12–14.

Greene, C. Willard
1930. The smelts of Lake Champlain. *In:* A biological survey of the Champlain Watershed. Suppl. to the 19th Ann. Rep. N. Y. Cons. Dept., 1929, pp. 105–129.

Hoover, Earl E.
1936. The spawning activities of fresh water smelt with special reference to the sex ratio. Copeia, 1936, No. 2, pp. 85–91.

Langlois, T. H.
1935. Notes on the spawning habits of the Atlantic smelt. Copeia, 1935, No. 3, pp. 141–142.

Van Oosten, John
1937. The dispersal of smelt, *Osmerus mordax* (Mitchill), in the Great Laakes region. Trans. Am. Fish. Soc., Vol. 66, (1936), pp. 160–171.
1947. Mortality of smelt, *Osmerus mordax* (Mitchill), in Lakes Huron and Michigan during the fall and winter of 1942–1943. Trans. Am. Fish. Soc., Vol. 74 (1944), pp. 310–337.

Warfel, Herbert E., Terrace P. Frost, and Warren H. Jones
1943. The smelt, *Osmerus mordax*, in Great Bay, New Hampshire. Trans. Am. Fish. Soc., Vol. 72 (1942), pp. 257–262.

VARIOUS SULFONAMIDE TREATMENTS OF FURUNCULOSIS IN BROOK TROUT, *SALVELINUS FONTINALIS*

S. F. Snieszko, J. S. Gutsell, and S. B. Friddle

U. S. Department of the Interior, Fish and Wildlife Service
Kearneysville, West Virginia

Abstract

Sulfamerazine, sulfamethazine, sulfathiazole, and sulfamerazine alternated at 4-day intervals with sulfathiazole, were compared in the treatment of furunculosis among yearling and fingerling brook trout at the Leetown Station of the U. S. Fish and Wildlife Service, Kearneysville, West Virginia, in 1947. The daily dosage rates were: for sulfamerazine and sulfamethazine, 6 grams per 100 pounds of fish (13.2 grams per 100 kilograms); for sulfathiazole, 12 grams per 100 pounds. The drugs were mixed thoroughly with the food.

The courses of the epizootics were very different in the two age groups. With yearlings, mortalities were as follows: controls, 100 percent; sulfathiazole, 75 percent; sulfamethazine, 62 percent; sulfamerazine-sulfathiazole, 43 percent; sulfamerazine, 29 percent. With fingerlings, treatment was initiated sooner after the onset of the disease. Although mortality was finally heavy in the fingerling control, sulfonamide therapy was very much more effective and losses correspondingly less severe. Mortalities were as follows: controls, 90 percent; sulfathiazole, 11 percent; sulfamerazine, 8 percent; sulfamerazine-sulfathiazole, 6 percent; sulfamethazine, 5 percent.

Sulfathiazole was markedly inferior to sulfamerazine. Sulfamethazine showed sufficient promise to warrant further trial. Sulfamerazine still seems the best for an acute infection and the drug most suitable for the treatment of furunculosis in brook trout.

Important was the revelation of the extreme difference in the courses of the epizootics and the apparent correlation of effectiveness of treatment with the type of epizootic. However, prompt initiation of treatment may largely explain the great effectiveness of the various drugs with the fingerlings.

Introduction

In the experiment carried out in 1945 (Gutsell, 1946, 1947, 1948), sulfamerazine was found to be most effective in the treatment of furunculosis and sulfathiazole was markedly beneficial. Sulfadiazine and sulfanilamide, tried late in the experiment, did not seem very helpful. Since then a new sulfonamide, sulfamethazine, has been recommended for a wide range of infectious diseases.

It seemed highly desirable to compare sulfamethazine with sulfamerazine in the treatment of furunculosis. Since sulfathiazole had shown beneficial effects and was so very much cheaper than sulfamerazine, this drug, at a high dosage rate, was included in the experiment. Because of the fear that

with long-continued treatment the causative agent of furunculosis, *Bacterium salmonicida,* might become resistant or "sulfamerazine fast" and because of the hope that the effectiveness of therapy would be increased by alternating sulfamerazine with a sulfonamide of quite different structure, it was decided to try alternated treatment with sulfamerazine and sulfathiazole over 4-day periods.

As a result of experiments run in 1946 (Gutsell, 1947; Gutsell and Snieszko, 1949), the daily dosage rate chosen for sulfamerazine was 6 grams per 100 pounds of fish (13.2 grams per 100 kilograms). Sulfamethazine was administered at the same rate as sulfamerazine. Sulfathiazole, because of its cheapness and inferiority to sulfamerazine, was administered at the daily rate of 12 grams per 100 pounds of fish. The drugs were mixed very carefully with the food.

Yearling and Fingerling Mortalities and Growth with the Various Treatments

The experiment was conducted in 1947 in two parts. In one, brook trout yearlings were used; in the other, fingerlings. In each part, there were four treatments and a control, each applied in two troughs. Ten adjacent upper troughs were used in each part (yearlings or fingerlings), and assignment of treatment was by random selection in one series, *i.e.,* without division into blocks. Fish were reweighed and food rations and drug dosages recalculated periodically.

On July 7 about 30 yearlings from a lot in which furunculosis had been causing heavy mortality for some time were weighed and placed in each trough. Treatment was started on July 8 and continued through August 4. The final counting was on August 5, 28 days after treatment was begun.

From the data on mortalities (Table 1 and Fig. 1) it may be seen that in the controls the daily death rate (percentage mortality per day) rose rapidly and comparatively evenly to 31.6 percent on the 11th elapsed day, more irregularly to 66.7 percent on the 16th day, when all fish but one were dead. This last fish died on the 28th day.

Among the fish given therapy, the total losses were as follows: sulfamerazine, 29 percent; sulfamerazine-sulfathiazole, 43 percent; sulfathiazole, 75 percent; sulfamethazine, 62 percent. The losses of weight were similar: controls, 100 percent; sulfamerazine, 20 percent; sulfamerazine-sulfathiazole, 41 percent; sulfathiazone, 75 percent; and sulfamethazine, 58 percent.

The second part of the experiment began on July 24, when approximately 100 fingerlings were introduced into each of 10 troughs from a pool in which furunculosis had appeared a few days previously. Treatment was begun on July 26 and continued through August 26 (31 days of treatment). The lots were kept under observation until September 12, or through 48 days after treatment was begun. Data on mortality are given in Table 2 and indicated graphically in Figure 2.

Developments were very different from those with yearlings (*cf.* Figs. 1 and 2). Among the controls, the mortality rate rose rapidly to 10 percent per day and for 2 weeks seldom varied much from this level. Then it dropped to 5 percent per day and for some 2½ weeks generally was some-

TABLE 1.—*Daily mortalities (numbers of fish) of yearling brook trout in the controls and in lots treated with sulfonamides*

[The control and each sulfonamide treatment was applied to two troughs here termed A and B]

Elapsed days	Control		Sulfamerazine		Sulfamerazine and sulfathiazole alternated[1]		Sulfathiazole		Sulfamethazine	
	A	B	A	B	A	B	A	B	A	B
1	1	..	..	..	1	1	2	..	1	1
2	..	1	..	..	..	..	4	1	1	..
3	1	1	..	2	3	3	..	..	2	..
4	2	..	1	..	1	2	..	2	2	1
5	1	2	..	..	2	..	1	4	1	2
6	1	3	..	2	..	1	2	..	1	..
7	4	3	1	1	2	..	2	..	4	3
8	3	1	..	..	..	..	1	1	1	3
9	2	6	2	1	..	..	..	..	..	4
10	1	4	1	..	3	..	2	..	1	2
11	5	1	1	..	..	..	1	1	1	1
12	1	3	..	..	1	..	1	1	..	1
13	1	1	..	..	..	..	..	..	..	..
14	2	..	..	..	1	..	1	..	..	1
15	2	..	..	..	..	..	..	..	1	1
16	1	1	..	..	1	..	1	..	..	..
17	..	..	1	..	..	..	1	1	1	..
18	..	..	..	..	..	..	..	2	..	..
19	..	..	1	..	..	..	1	1	..	..
20	..	..	..	1	..	1	..	..	..	..
21	..	..	..	..	..	..	..	..	..	..
22	..	..	..	1	..	..	..	1	..	..
23	..	..	..	..	..	..	2	..	..	..
24	..	..	..	..	..	..	2	1	1	..
25	..	..	1	..	..	..	..	..	..	..
26	..	..	..	..	..	..	1	..	..	..
27	..	..	..	..	..	..	..	..	..	..
28	..	1	..	..	1	..	2	1	..	..
Total mortalities..	28	28	9	8	16	8	27	17	18	20
Original number.....	28	28	30	29	30	26	30	29	31	30

[1] Drugs were alternated every 4 days; treatment was started with sulfamerazine

what under this level. Except for 2 days, mortality occurred daily from the 2nd to the 37th elapsed day. The total mortality was high (90 percent). Among the lots treated with sulfonamides, total mortalities were as follows: sulfamerazine, 8 percent; sulfamerazine-sulfathiazole, 6 percent; sulfathiazole, 12 percent; sulfamethazine, 6 percent.

The surviving brook trout were transferred from the control troughs to a small trough and kept under observation. Within a few weeks the trout began to die. Bacteriological examination revealed infection with *B. sal-*

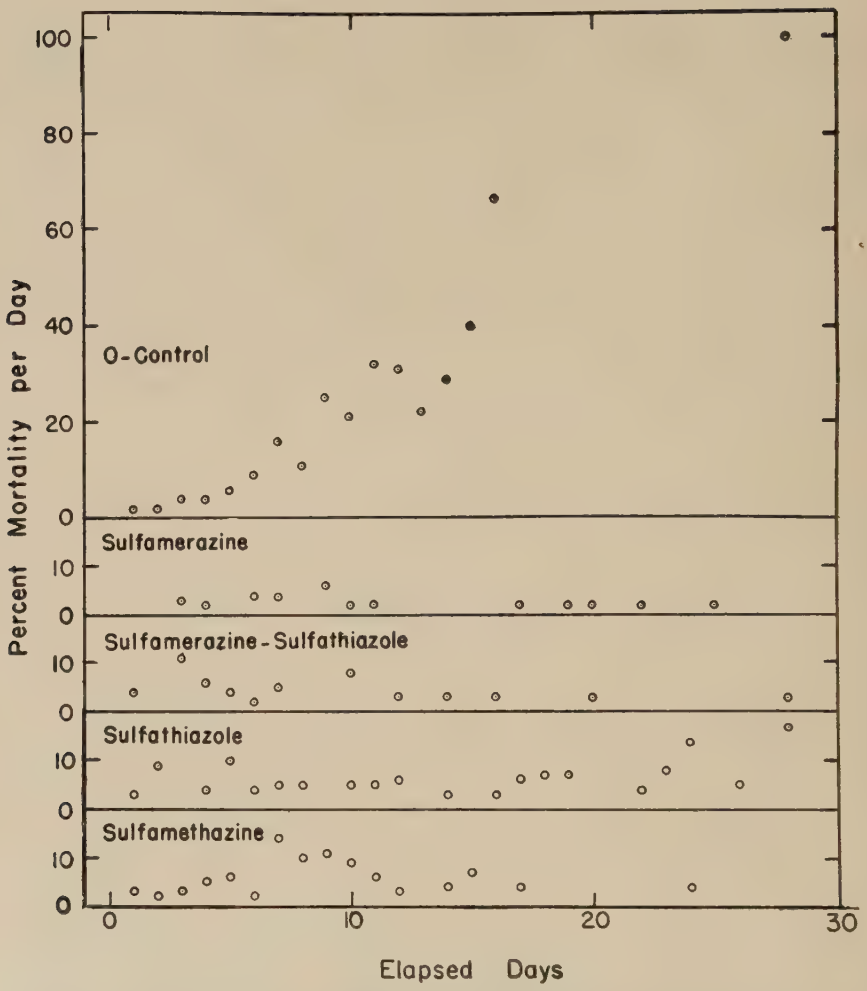

FIGURE 1.—Mortalities of yearling brook trout. Each dot represents the deaths during one day in two troughs as a percentage of the number alive in these two troughs the preceding day.

monicida. This result is in accord with the early observations of Mackie *et al.* (1935) that trout surviving one attack of furunculosis are not permanently resistant or immune to this disease.

Losses among the fingerlings treated with sulfonamides were sufficiently low to provide evidence on the relative effect of the various treatments on growth. The average percentage increases in weight per fish with the various sulfonamide treatments were as follows: sulfamerazine, 57; sulfamera-

TABLE 2.—*Daily mortalities (numbers of fish) of fingerling brook trout in the controls and in the lots treated with sulfonamides*

[The control and each sulfonamide treatment was applied to two troughs here termed A and B]

Elapsed days	Control		Sulfamerazine		Sulfamerazine and sulfathiazole alternated[1]		Sulfathiazole		Sulfamethazine	
	A	B	A	B	A	B	A	B	A	B
1	..	..	1	..	..	..	1	..	2	..
2	..	2	1	1	1	..	..	1	..	..
3	2	3	..	..	..	..	2	..	..	..
4	..	2	..	1	2	..	1	..	..	..
5	8	11	..	1	1	..	..	..	..	1
6	10	8	..	1	..	..	..	..	..	..
7	5	9	..	..	..	..	..	1	..	..
8	5	6	1	..	..	..	..	..	..	..
9	2	7	..	..	..	..	..	..	..	2
10	2	6	..	1	..	..	1	1	..	1
11	9	14	..	..	..	..	..	..	..	..
12	3	7	..	..	..	..	1	1	2	..
13	2	2	..	..	..	..	..	..	..	..
14	5	1	..	..	..	..	..	3	..	1
15	2	2	..	..	..	..	3	..	..	..
16	3	5	1	1	..	..	1	..	..	..
17	2	4	..	3	..	..	..	..	..	..
18	3	1	..	..	..	..	..	1	..	..
19	5	1	..	..	..	..	..	2	..	..
20	1	1	..	..	..	..	..	..	..	..
21	1	..	..	..	..	..	1	..	..	..
22	2	..	..	..	..	..	..	..	..	..
23	1	..	..	..	..	..	..	..	..	..
24	1	..	..	..	2	..	..	..	..	..
25	1	..	..	..	..	..	..	..	..	..
26	..	1	..	..	1	..	..	..	..	..
27	..	..	..	..	..	..	..	..	..	..
28	..	1	..	..	..	..	..	..	..	..
29	2	..	..	..	..	..	..	..	..	..
30	..	..	..	..	..	..	..	1	1	..
31	1	..	..	..	..	..	..	..	..	..
32	..	1	..	..	..	..	..	..	..	..
33	..	..	..	..	..	2	..	1	..	..
34	2	..	..	..	..	1	..	..	..	..
35	1	..	..	..	..	..	..	..	..	..
36	1	..	..	..	..	..	..	..	..	..
37	1	..	..	..	..	..	..	..	..	..
38	..	..	1	..	..	..	..	..	..	..
39–41	..	..	..	..	..	..	..	..	..	..
42	1	..	..	..	..	..	..	..	..	..
43–47	..	..	..	..	..	..	..	..	..	..
48	..	..	1	..	..	1	..	..	..	..
Total mortalities..	84	95	6	9	7	4	11	12	5	5
Original number.....	100	99	100	98	101	99	101	100	96	100

[1] Drugs were alternated every 4 days; treatment was started with sulfamerazine

zine-sulfathiazole, 37; sulfathiazole, 22; sulfamethazine, 68. So far as known, sulfonamides affect the growth of trout only by reducing consumption of food containing the drug (evidently disliked by trout). Apparently sulfamethazine affects food consumption even less than sulfa-

merazine. Of course, the growth-retarding influence of sulfathiazole was increased by the heavier dosage rate used with this drug.

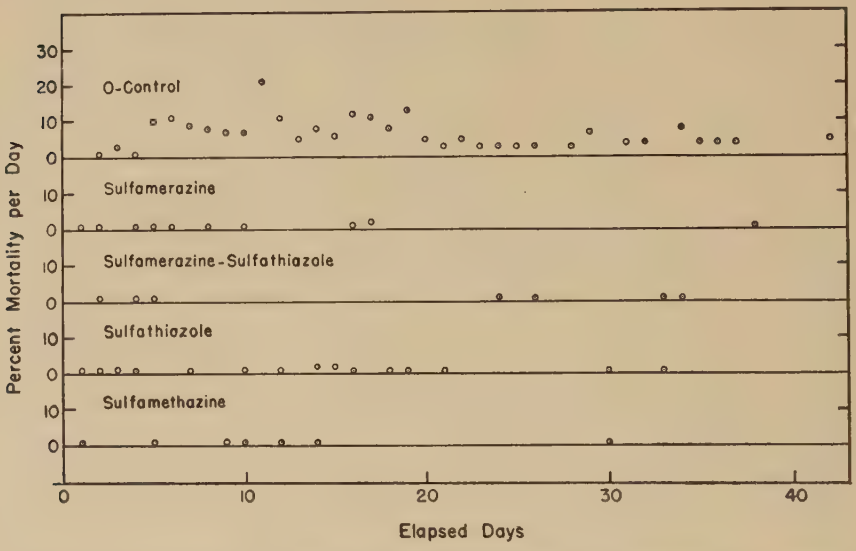

FIGURE 2.—Mortalities of fingerling brook trout. Each dot represents the deaths during one day in two troughs, as a percentage of the number alive in these two troughs the preceding day.

BACTERIOLOGICAL EXAMINATION OF DEAD BROOK TROUT

The results of bacteriological examination of dead fish are given in Table 3. Of the 417 dead, 227 or 54 percent were examined. Of those examined, 205 or 90 percent were found to be infected by *B. salmonicida*.

TABLE 3.—*Bacteriological examination of dead trout for* Bacterium salmonicida
The numbers of fish in which the examination gave positive or negative results are recorded in columns headed P and N, respectively]

Size class of fish	Method of treatment and results of examination for *B. salmonicida*									
	Control		Sulfamerazine		Sulfamerazine and sulfathiazole alternated[1]		Sulfathiazole		Sulfamethazine	
	P	N	P	N	P	N	P	N	P	N
Yearlings.....	28	1	14	3	18	6	35	2	37	0
Fingerlings....	32	0	15	0	3	6	15	4	8	0

[1]Drugs were alternated every 4 days; treatment was started with sulfamerazine

Comparative Effectiveness of Different Treatments

Not the least interesting aspect of this experiment was the surprising difference in the courses of the epizootics among the yearling and fingerling controls. The yearlings' mortality rate increased rapidly until mortality was almost complete (98 percent) in 16 days. The mortality rate of the fingerlings was seldom high, but was almost uninterrupted for 37 days (total mortality, 90 percent).

Equally or more surprising was the much greater effectiveness of sulfonamide therapy with the fingerlings as compared with the yearlings. Whereas the mortality among the yearlings receiving sulfonamides varied from 29 to 75 percent, with the fingerlings it varied only from 5 to 11 percent.

How much of this greater effectiveness and remarkable efficiency in the treatment of furunculosis among the fingerlings was due to the nature of the epizootic and how much to prompt initiation of treatment cannot be said. Undoubtedly prompt initiation of treatment is important, but there can be little doubt that the type of epizootic is important too.

Comparative evaluation of the various treatments is not easy. Sulfathiazole had the worst record both with fingerlings and yearlings. In the yearlings, not only was mortality the highest but it also continued undiminished up to the end of the experiment.

With fingerlings, results from sulfamethazine and sulfamerazine-sulfathiazole therapy were statistically superior to those from sulfathiazole treatment. However, with losses so very low and with 13 deaths among 200 fish through 48 days separating the highest from the lowest loss, the authors feel that this part of the experiment is valuable chiefly for showing that prompt treatment with any of these sulfonamides may be remarkably effective, at least against certain types of outbreaks.

With yearlings, the superiority of sulfamerazine over sulfathiazole was statistically significant, but its advantage over sulfamethazine and the superiority of sulfamerazine-sulfathiazole over sulfathiazole were somewhat short of significance (F below the 5-percent point).

Although losses of yearlings with sulfamethazine therapy were high, they occurred early, and it may be that this sulfonamide is among the more effective drugs for the treatment of furunculosis. Certainly it should be tested further.

Sulfathiazole, although effective in certain cases, is so definitely inferior that its use alone cannot be recommended. Alternated with sulfamerazine it did fairly well, but evidence is insufficient to warrant recommendation of this combination. At this time, sulfamerazine appears to be the most effective in acute outbreaks and the drug to choose for the treatment of furunculosis in brook trout.

Acknowledgements

Sharpe and Dohme and the American Cyanamid Company very kindly donated sulfonamides for use in this experiment.

Dr. S. F. Scheidy, Veterinary Medical Director, Medical Research Division, Sharpe and Dohme, and Dr. Mark Welsh, Director, Animal Industry Section, Lederle Laboratory Division, American Cyanamid Company gave valued advice.

Within the Fish and Wildlife Service, Dr. C. M. Mottley, formerly Chief, Section of Inland Fisheries, gave valuable help in the analysis of data, and Mr. E. W. Surber, Chief, Eastern Fish-Cultural Investigations, in immediate charge of the Leetown Station, put the necessary fish and fish troughs at our disposal.

Literature Cited

Gutsell, James S.

1946. Sulfa drugs and the treatment of furunculosis in trout. Science, Vol. 104, No. 2691, pp. 85–86.

1947. Furunculosis and its treatment. The Progressive Fish-Culturist, Vol. 9, No. 1, pp. 13–20.

1948. The value of certain drugs, especially sulfa drugs, in the treatment of furunculosis in brook trout (*Salvelinus fontinalis*). Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 187–199.

Gutsell, James S., and S. F. Snieszko

1949. Dosage of sulfamerazine in the treatment of furunculosis in brook trout (*Salvelinus fontinalis*). Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 82–96.

Mackie, T. J., J. A. Arkwright, T. E. Pryce-Tannat, J. C. Mottram, W. Douglass Johnstone, and J. M. Menzies

1935. Final report of the Furunculosis Committee. His Majesty's Stationery Office, Edinburgh, 67 pp.

GROWTH-CONTROL CHARTS APPLIED TO ATLANTIC SALMON

GEORGE A. ROUNSEFELL

U. S. Department of the Interior, Fish and Wildlife Service
Orono, Maine

AND

LYNDON H. BOND

Maine Inland Fisheries and Game Department
Orono, Maine

ABSTRACT

Growth data for Atlantic salmon (*Salmo salar*) over an 8-year period form the basis for a control chart whereby increase in growth can be followed throughout the season, and any abnormalities quickly detected.

A growth-control chart has been constructed to show the normal size-expectancy of young Atlantic salmon at progressive dates after spawning. The data used are the number of salmon per pound in lots of fish planted from the United States Fishery Station at Craig Brook, Maine, for the eight groups of fish spawned in the years from 1939 to 1946. Because the variation in the number per pound is proportional to the size of the mean it was necessary to transform the data on the number of fish per pound into logarithms.

The fish of the 1945 brood year were excluded in fitting the regression curve because they were graded for size during the twelfth month after spawning (October). The original data are given in Table 1. The resulting regression line of the logarithm of the number per pound on the number of months after spawning ($Ey = 3.493532 - 0.084433\ X$) is shown in Figure 1. The dotted lines about the regression line show one and two standard errors of estimate (0.167).

Although not used in fitting the regression curve, the weights of fish of the 1945 brood are shown in Figure 1 by large black dots. Superiority in size attained by salmon of the 1945 brood year is immediately apparent. This fact suggests that grading of young salmon has a significant influence on their growth.

The easiest way to use this method is to employ semi-log paper and plot the actual number of fish per pound as the ordinate with the number of months on the arithmetic scale as the abscissa. Any significant departure from the normal can be detected quickly by merely noting any points falling outside of the two standard errors of estimate.

TABLE 1.—*Size of Atlantic salmon when stocked*

Brood year	Months after spawning	Number per pound	Logarithm of number per pound
1939	14	160	2.204
	14	161	2.207
	19	81	1.908
	20	78	1.892
1940	9	611	2.786
	10	596	2.775
	11	533	2.727
	23	31	1.492
	24	25	1.398
	31	15	1.176
1941	11	466	2.668
	11	465	2.667
	11	462	2.665
	12	156	2.193
	19	128	2.107
	19	68	1.833
	19	85	1.929
	19	25	1.398
	21	32	1.505
1942	18	75	1.875
	19	79	1.898
	19	86	1.935
	22	63	1.799
	23	31	1.492
	24	23	1.362
	24	24	1.380
	33	9	0.954
	33	4	0.602
1943	20	50	1.699
	21	36	1.556
	23	31	1.491
	31	13	1.114
1944	19	70	1.845
	23	19	1.279
	23	14	1.146
	31	6	0.778
1945	19	44	1.644
	19	45	1.653
	19	55	1.740
	20	37	1.568
	20	22	1.343
	20	42	1.623
	21	19	1.279
	21	16	1.204
	21	14	1.146
1946	19	92	1.964
	19	80	1.903
	19	78	1.892

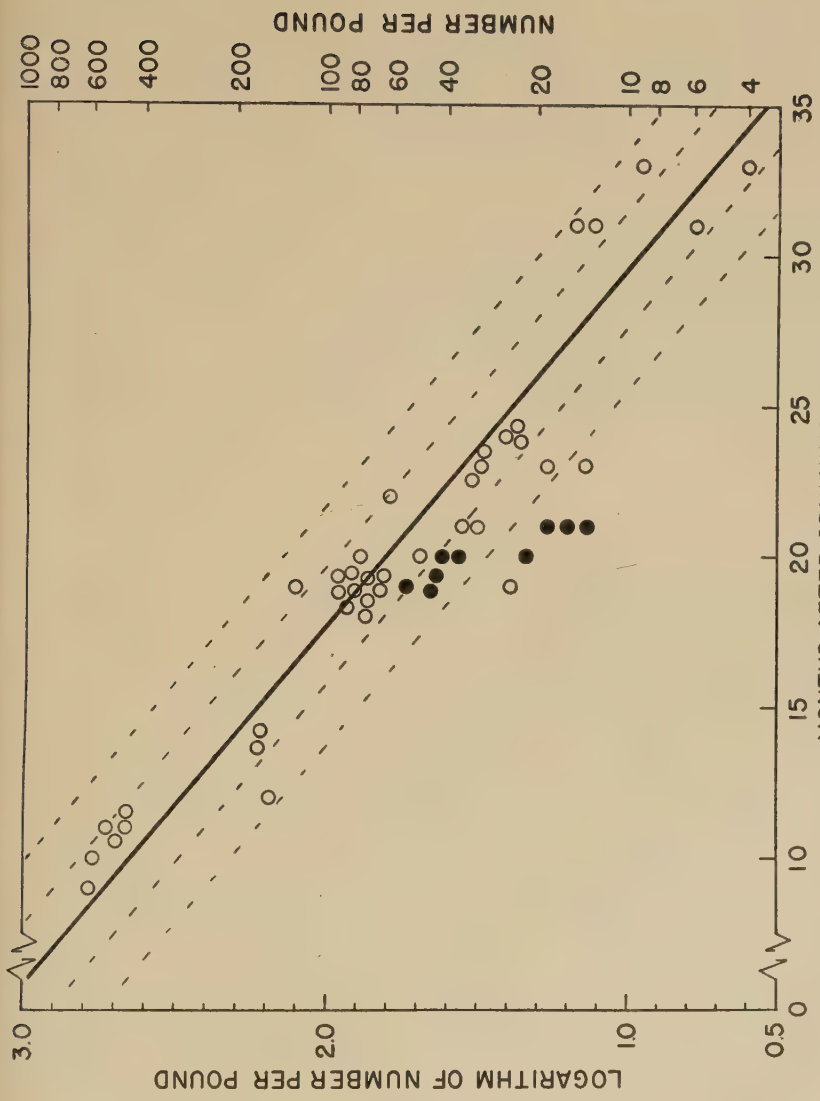

FIGURE 1.—Regression of the logarithm of the number of Atlantic salmon per pound on the number of months after spawning. See text for explanation.

TOXICITY OF FERRO- AND FERRICYANIDE SOLUTIONS TO FISH, AND DETERMINATION OF THE CAUSE OF MORTALITY

George Edgar Burdick and Morris Lipschuetz

New York Conservation Department
Rochester, New York

Abstract

The investigation of the causes of a fish kill in waters containing ferro- and ferricyanide at concentrations far under those generally accepted as non-lethal have shown these low concentrations to be lethal due to photo-decomposition and release of the cyanide ion. Experimental data place the toxic level of these compounds, under similar conditions of light intensity, at a concentration between 1 and 2 p.p.m. This level is assumed to vary slightly under natural conditions with latitude, period of the year, temperature, water turbulence, and interferences. Rapid development of toxicity has been demonstrated at a concentration of 2 p.p.m. of either potassium ferro- or ferricyanide.

Introduction

A fish kill extending over 12 miles in one of the streams in this state was found to be associated with the discharge of ferro- and ferricyanides in an industrial effluent. The concentration found to be toxic in this stream was far below that listed in the literature for these compounds. These findings led to a study to determine the cause of the mortality and to establish tentatively the lethal level for these compounds under conditions present in natural waters.

Potassium ferrocyanide and ferricyanide have not been considered as particularly toxic. Ellis (1937) quoted Penny and Adams to the effect that neither is toxic to minnows and goldfish at a concentration of 2,000 p.p.m., and Weigelt, Saare, and Schwab that a concentration of 8,732 p.p.m. of potassium ferrocyanide is non-toxic to trout in a 1-hour exposure. Schaut (1939) stated that 17.1 p.p.m. of potassium ferricyanide had no effect over a 1-hour exposure, and the same concentration of potassium ferrocyanide was non-toxic over a 70-day exposure period (the concentration appeared to diminish during this period).

Decomposition of Potassium Ferro- and Ferricyanide Solutions

That both of these substances are decomposable to some extent under the influence of light, more readily so in the presence of oxygen, has been reported previously in the chemical literature.

Schwarz and Tede (1927) have observed that 10 percent of an N/10 solution of potassium ferricyanide was decomposed by light from a carbon arc over a period of 3 hours. The products were stated to be potassium

ferrocyanide, cyanogen, and colloidal ferric hydroxide.. Baudisch and Bass (1922) suggested a mechanism for the photodecomposition of potassium ferrocyanide to produce hydrogen cyanide with the release of one-sixth of the cyanide. This reaction is considered to be reversible, dependent upon the conditions of light and dark, and is accelerated by the presence of oxygen. Under prolonged exposure, the reaction becomes irreversible with precipitation of ferrous hydroxide implying a further decomposition of the primary reaction product.

The formation of cyanide, or hydrocyanic acid, from ferro- and ferricyanides suggests a possible development of toxicity from low concentrations of these compounds on bright, sunny days. . The residual cyanide content in various concentrations of these compounds exposed to natural sunlight during the spring and fall months has been investigated in this laboratory. Although it has not been possible to carry out any studies during the midsummer months when the light intensity should be greater and the decomposition theoretically more nearly complete and more rapid, results have indicated the production of toxic concentrations of cyanide at very low levels of potassium ferro- and ferricyanide..

Development of Residual Cyanide in Ferro- and Ferricyanide Solutions in Sunlight

A number of concentrations of potassium ferro- and ferricyanide were made up in Rochester tap water and placed in the sun, in diffuse light, and in the dark. Rochester tap water is considered to be about average for New York State, with a pH of 7.2-7.3, carbon dioxide of 0.5-1.0 p.p.m. and a methyl-orange alkalinity of 57-60 p.p.m. These solutions were tested periodically for cyanide by the cyanogen bromide-pyridine-benzidine method of Aldridge (1944 and 1945) which works satisfactorily in the presence of ferro- and ferricyanide when those compounds are in concentrations that will not color the solution strongly. At very high concentrations, the analyses were conducted according to the method suggested by Lang (1925).

Cyanide Formation in Sunlight.—All exposures were made in open vessels, either large beakers or aquaria. The solutions were stirred periodically to prevent localized high concentrations of decomposition products. A summary of the maximum residual concentrations of the cyanide ion formed from potassium ferrocyanide and ferricyanide is presented in Tables 1 and 2. In the same tables are given exposure times and physical conditions.

Lower temperatures, almost without exception, result in a higher residual cyanide concentration in comparable solutions, indicating a reduction in losses to the atmosphere from the surface of the solution.

Data collected for different concentrations of potassium ferrocyanide and similar data for ferricyanides exposed under identical light and other conditions form the basis for the graphical presentation of the level of

TABLE 1.—*Cyanide formation from potassium ferrocyanide*

Ferrocyanide concentration (p.p.m.)	Date	Time	Light condition	Temperature range (°F.)	CN^- (p.p.m.)
1.0	May 21, 1948	11:30 a. m.– 3:15 p. m.	Intermittent sunlight	62–66	[1]0.05
1.0	May 25, 1948	9:30 a. m.–11:30 a. m.	Sunlight	72–76	0.16
1.0	May 25, 1948	9:30 a. m.–10:30 a. m.	do.	72–76	0.29
2.0	May 25, 1948	2:00 p. m.– 3:30 p. m.	do.	72–74	0.365
2.0	May 12, 1947	11:00 a. m.– 1:00 p. m.	do.	70–72	0.48
3.0	May 25, 1948	9:30 a. m.–10:30 a. m.	do.	72–76	0.72
4.35	Sept. 4, 1945	1:25 p. m.– 4:08 p. m.	do.	75–88	0.50
5.0	May 19, 1948	9:45 a. m.–12:45 p. m.	do.	66–70	0.59
5.0	May 21, 1948	11:30 a. m.– 1:00 p. m.	Intermittent sunlight	62–66	0.84
8.7	Sept. 4, 1945	1:25 p. m.– 3:15 p. m.	Sunlight	75–86	0.85
8.7	Sept. 5, 1945	10:55 a. m.– 1:40 p. m.	do.	68–69	0.95
8.7	Sept. 5, 1945	11:00 a. m.– 2:40 p. m.	do.	76–99	0.90
10.0	Oct. 10, 1945	10:40 a. m.– 2:13 p. m.	do.	66–76	0.80
10.0	May 19, 1948	9:45 a. m.– 1:45 p. m.	do.	66–70	1.72
17.6	Sept. 4, 1945	1:25 p. m.– 3:45 p. m.	do.	75–87	1.25
20.0	May 19, 1948	9:45 a. m.– 2:45 p. m.	do.	66–70	3.3
43.9	Sept. 4, 1945	1:25 p. m.– 3:40 p. m.	do.	75–87	1.35
100.0	May 19, 1948	9:45 a. m.– 2:45 p. m.	do.	66–70	6.6

[1] This low rate of decomposition is assumed to be due to interferences. This water had a pH of 7.6 as compared with the usual pH of 7.2-7.3. Use of aquarium water (first run of May 25, 1948—concentration of 1 p. p. m.) somewhat corrected this condition, but use of distilled water (second run of May 25) buffered with 0.3 grams of sodium bicarbonate per liter showed a still higher residual cyanide.

residual cyanide content during progressive exposure of these substances shown in Figure 1. The conformation of the curves appear to be different, but as equivalent concentrations of the two compounds exposed simultaneously have required approximately an equal time for development of the maximum residual cyanide level, this disagreement is believed to be due to difference in light intensity, rather than an essential difference in the mechanism of decomposition.

A series of determinations of the residual cyanide content in low concentrations of potassium ferro- and ferricyanide in aquarium water, showed some variation present in the curves of the two substances, but the general conformation is similar. With the exception of the 1-p.p.m. solutions the ferrocyanide attains a higher concentration of cyanide. In this particular case the order of magnitude is reversed, and is corrected only by substitution of a bicarbonate buffered dilution water for the aquarium water first

TABLE 2.—*Cyanide formation from potassium ferricyanide*

[All solutions were exposed to continuous sunlight]

Ferricyanide concentration (p.p.m.)	Date	Time	Temperature range (°F.)	CN^- (p.p.m.)
1.0	May 25, 1948	9:30 a. m.–10:30 a. m.	72–76	0.205
2.0	May 25, 1948	2:00 p. m.– 3:00 p. m.	72–74	0.36
2.0	May 12, 1947	11:00 a. m.– 2:00 p. m.	70–72	0.48
3.0	May 25, 1948	9:30 a. m.–10:30 a. m.	72–76	0.64
5.0	Oct. 9, 1945	10:40 a. m.– 3:15 p. m.	67–75	1.05
10.0	Oct. 9, 1945	10:40 a. m.– 2:10 p. m.	66–76	1.8
20.0	Oct. 9, 1945	10:40 a. m.– 3:16 p. m.	66–75	2.8
100.0	Oct. 9, 1945	10:40 a. m.– 3:17 p. m.	66–75	4.5

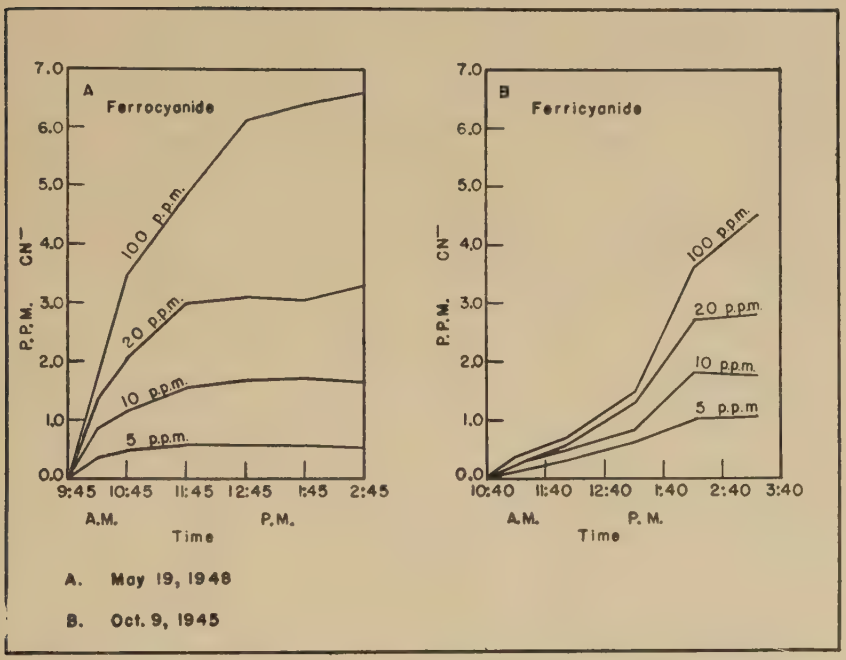

FIGURE 1.—A. Level of residual cyanide content during exposure of different concentrations of ferrocyanide under similar light intensities. B. The same for ferricyanide.

used. The data from these experiments are given graphically in Figure 2.

Residual Cyanide Formation in Diffuse Light and Dark.—Low concentrations of potassium ferrocyanide, in diffused light in the laboratory failed to show any decomposition at a rate sufficiently high to be toxic to fish life. The highest residual cyanide determined in solutions under 100 p.p.m. was 0.05 p.p.m. of cyanide ion. A 4,000-p.p.m. solution which was toxic to fish within 24 hours under these conditions showed a cyanide content of 0.3 p.p.m. An even lower rate of development of residual cyanide was given by low concentrations of potassium ferrocyanide in the dark; the highest reading on concentrations below 100 p.p.m. was 0.03 p.p.m. of cyanide ion. A 4,000-p.p.m. solution produced 100-percent mortality of fish within 48 hours and when tested at the end of 72 hours had 0.3-0.6 p.p.m. of cyanide.

Factors other than Light Affecting the Residual Cyanide Content.—The maximum concentration of cyanide obtained in an open vessel, stirred occasionally, represents the total released, minus losses to the atmosphere and from recombination of the decomposition products or reaction with substances present in the water. This fact is shown graphically in the upper part of Figure 3, where residual concentrations of cyanide in a closed pyrex glass container and an open container are compared. The slight

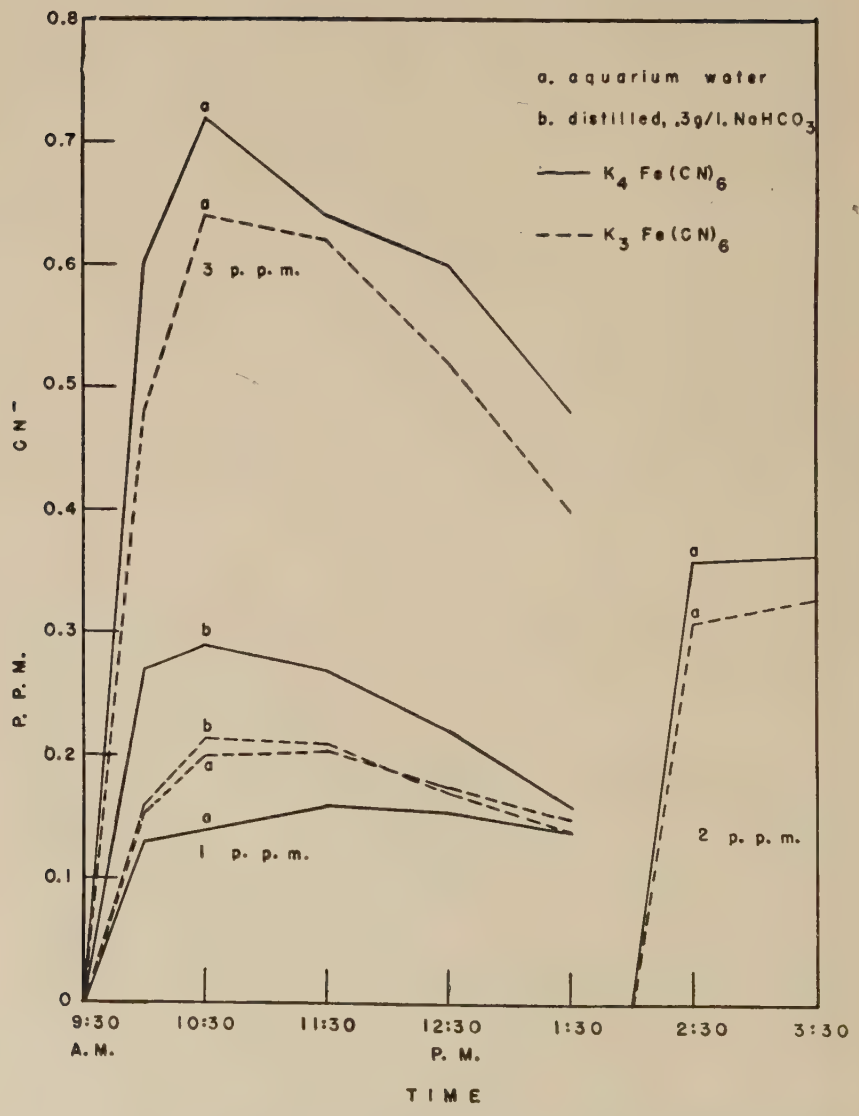

FIGURE 2.—Residual cyanide content during exposure of 1-, 2-, and 3-p.p.m. solutions in aquarium water and buffered distilled water, May 25, 1948.

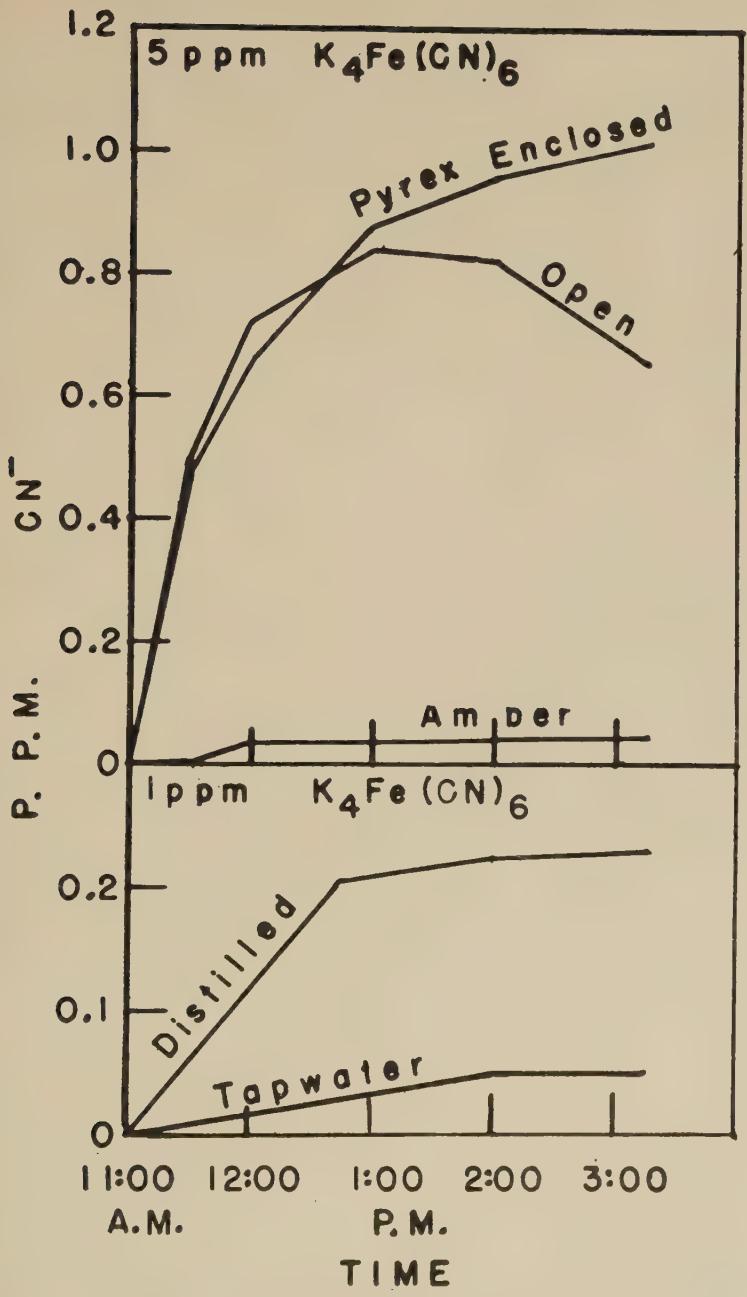

FIGURE 3.—Experiments with ferrocyanide, May 21, 1948. Upper: Effect of type of container on cyanide concentration. Lower: Residual cyanide in 1-p.p.m. solutions of potassium ferrocyanide in open containers when dissolved in tapwater and distilled water.

reduction of actinic effect in the closed vessel causes a lag in cyanide production, but the higher rate of loss in the open container brings the two to an equal value. Shortly thereafter the rate of loss in the open container exceeds the rate of formation and a decrease in cyanide occurs. In the closed container the concentration was still increasing at the end of the exposure period.

The rate of decomposition in a closed container of Kimball low actinic amber glassware is greatly decreased with only 0.045 p.p.m. of cyanide produced during the period when 1.02 p.p.m. developed in the closed pyrex container. An efficiency of only 4.4 percent in the amber glass indicated that most of the active wavelengths of light were filtered out.

In 1-p.p.m. concentrations of ferro- and ferricyanide dissolved in tap water, the ferrocyanide was found to contain a very low residual cyanide content after exposure to sunlight. The ferricyanide solution was not affected to the same extent. The use of closed containers failed to produce any significant increase in cyanide content and the low level cannot be due to surface loss.

A comparison of the cyanide content in 1-p.p.m. solutions of potassium ferrocyanide in distilled and freshly drawn tap water is to be found in the lower part of Figure 3. The results shown there, together with the behavior of the 1-p.p.m. solutions in aquarium water and bicarbonate-buffered distilled water, shown in Figure 2, demonstrate interferences to the development of the residual cyanide content to be present in Rochester tap-water. The interference is less in water taken from an aquarium containing fish than in fresh tap water. The use of distilled water buffered with bicarbonate gives values approximately equal to those from distilled water.

The cause of this effect upon the development of residual cyanide is not known. Theoretically the explanation could lie in the retarding of the decomposition of the ferrocyanide, the removal of part of the soluble salt as an insoluble complex, or the destruction of a part of the released cyanide. The pH of the solutions might produce some difference between reactions in distilled and tap water, since the pH was found to be 6.1 in the former compared to 7.67 in the latter. The pH is also lower in the aquarium water containing fish than in freshly drawn tap water. This hypothesis does not hold for the bicarbonate-buffered distilled water, as the initial pH is higher than that found in any of the other solutions.

Contact with fish appears to remove some of the interfering substance, as does the process of distillation. Among the substances which might be removed in both instances are metallic ions. Such an interference with the ferrocyanide solutions could be expected if the water were to contain small quantities of zinc, which would have little or no effect on ferricyanide solutions. Other substances might behave in a like manner. As the determination of zinc in low concentration is subject to high error, its estimation was not attempted.

The possibility that a similar interference may be present in natural

waters must be considered in the application of the data presented here to toxicity problems involving these compounds.

Toxicity of Ferro- and Ferricyanide Solutions to Fish

The determination of toxic concentrations of these compounds can be only approximate, since a part of the decomposition reaction is reversible in the dark, or in weaker light. A determination of the amount of released cyanide that is recombined or lost through secondary reactions under these conditions has indicated that after a 5-hour exposure of concentrations from 10 to 100 p.p.m. of potassium ferrocyanide to sunlight a decrease in concentration of cyanide of 8 to 10 percent was obtained in 18 hours when the solution was held in a closed container. Lower concentrations showed a higher percentage of recombinations, or loss of cyanide. Toxic concentrations must produce and maintain a cyanide content sufficient to be lethal to fish within the period of exposure. High temperature increases the toxicity of cyanide to fishes, but it also increases its rate of removal from solution.

A cyanide content of approximately 0.19 p.p.m. has been determined in this laboratory to be toxic to *Rhinichthys atratulus atratulus* and *Semotilus atromaculatus atromaculatus*. At this level 100-percent mortality occurs within 76 hours and 50 percent mortality within 48 hours. It is not believed that the ferro- or ferricyanide contents which would produce this quantity of cyanide are toxic under natural conditions, since losses to the atmosphere, and the limited formation at night would reduce the available cyanide during a part of the exposure period. Although 1 p.p.m. of either potassium ferro- or ferricyanide will produce a cyanide content over 0.19 p.p.m. under proper conditions, fish mortality was caused only once in the laboratory with this concentration.

Since the rate of decomposition is variable, two methods are available to determine lethal concentrations of the salts: (1) use every exposure as a bio-assay, or, (2) from previous determinations of the toxicity of cyanide to the test species, consider all solutions toxic when this level is reached. A combination of these two methods has been used. Bio-assays with test fish, either at the start, or during the period of exposure to sunlight have been supplemented by direct cyanide determinations on solutions exposed to sunlight.

Previous data on the toxicity of cyanide to *Rhinichthys atratulus atratulus* and *Semotilus atromaculatus atromaculatus* (unpublished) show that the lowest level of cyanide lethal over a short exposure time is approximately 0.3 p.p.m. of CN^-. This concentration produced 100-percent mortality in 28 to 30 hours and 50-percent mortality in 5¼ to 7½ hours. This latter time can be approximated in any day within the light period calculated to be effective in producing and maintaining a lethal cyanide content. The toxicity of this concentration of cyanide formed in potassium ferro- and ferricyanide solutions has been confirmed by bio-assay, as the level was

approached. Along with all assays, controls were exposed to the same physical conditions. A brief summary of the bio-assays conducted at low levels of ferro- and ferricyanide appears in table 3.

Toxic effect was not evident in solutions under 2,000 p.p.m. in diffuse light or in the dark. Though some evidence of cyanide formation was found at times under these conditions, the level was too low to be toxic,

TABLE 3.—*Bio-assays of potassium salts, direct sunlight*

Salt and concentration	Species	CN^- (p.p.m.)	Preliminary exposure	Results
Ferrocyanide (1 p.p.m.)	*R.*[1] *atratulus* *S.*[2] *atromaculatus*	.05–.16	Variable	No effect to 5 hours
Ferrocyanide (2 p.p.m.)	*R. atratulus* *S. atromaculatus* *H.*[3] *regius*	.365–.48	½ to 1½ hours	Dead, from 1 to 1½ hours
Ferrocyanide (3 p.p.m.)	*S. atromaculatus*	.72	½ hour	Dead, 25 minutes
Ferrocyanide (5 p.p.m.)	*R. atratulus* *S. atromaculatus* *H. regius*	.5–.84	None to 3 hours	All fish died—Time variable
Ferricyanide (1 p.p.m.)	*R. atratulus* *S. atromaculatus*	?–.205	Variable	Lethal only once. CN^- not determined.
Ferricyanide (2 p.p.m.)	*S. atromaculatus* *N.*[4] *atherinoides*	.36–.48	½ to 1½ hours	Dead, from 13-38 minutes
Ferricyanide (3 p.p.m.)	*S. atromaculatus*	.64	½ hour	Dead, 2½ hours
Ferricyanide (5 p.p.m.)	*R. atratulus*	1.0	3 hours	Dead, 47 minutes

[1] *Rhinichthys*
[2] *Semotilus*
[3] *Hybognathus*
[4] *Notropis*

except in solutions of high concentration. Potassium ferrocyanide at a concentration of 4,000 p.p.m. produced 100-percent mortality in 24 to 48 hours, with a determined cyanide content at the end of 0.3 to 0.6 p.p.m.

The above data demonstrate that, under the conditions of the bio-assays conducted at this laboratory, the toxic level for both potassium ferro- and ferricyanide lies between 1 and 2 p.p.m. It appears that a large part of the actinic rays producing decomposition are in the ultra-violet wave lengths. Since no data are available for June, July, August, and September when these components are supposedly higher, work during this period may indicate a slightly lower figure.

The graph of the maximum development of residual cyanide from low concentrations of potassium ferro- and ferricyanide indicates that the arbitrary chosen toxic level of 0.3 p.p.m. of cyanide ion can be reached when the concentration of ferrocyanide is 1.45 p.p.m. and that of ferricyanide 1.34 p.p.m. (Fig. 4).

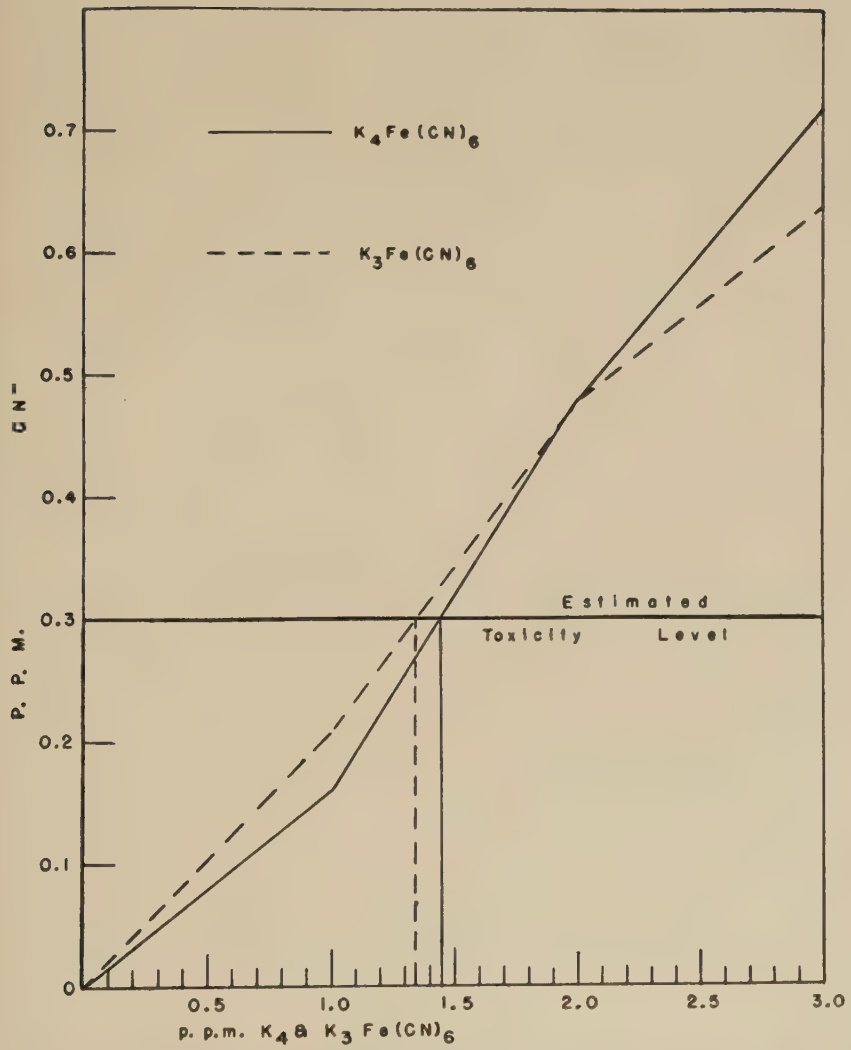

FIGURE 4.—Theoretical toxic levels of potassium ferro- and ferricyanide based on maximum determined residual cyanide in sunlight.

SIGNIFICANCE AND LIMITATIONS OF THE PRESENT FINDINGS

Experimental work has shown that potassium ferro- and ferricyanide solutions in concentrations as low as 2 p.p.m. are toxic to fish life in the presence of sunlight, while 1 p.p.m. under the light conditions prevailing

during these studies was not commonly lethal. It is not believed that these figures are final as work during the summer months when light intensity is higher should lower them. Summer work is impossible at this laboratory; therefore, this preliminary study is presented. The experimental data indicate a need of correction of the previously established figures on the toxicity of potassium ferro- and ferricyanide solutions which it is believed are in error due to failure to simulate natural conditions.

It has been established that the toxicity in low concentrations is due to cyanide resulting from decomposition of the complex molecules. It is further indicated that the toxicity of high concentrations of potassium ferro- and ferricyanide in diffuse light or in the dark is due to the formation of the cyanide ion, though at a much slower rate.

Literature Cited

Aldridge, W. N.
1944. A new method for the estimation of micro quantities of cyanide and thiocyanate Analyst, Vol. 69, pp. 262–265.
1945. Estimation of micro quantities of cyanide and thiocyanate. Analyst, Vol. 70, pp. 474–475.

Baudisch, Oscar and Laurence W. Bass
1922. Eisen als licht-chemischer Katalyzator, I Über die Zersetzung von Ferrocyankalium im Tageslicht. Ber. Deut. Chem. Gesell. Bd. 55, Ab.B, S. 2,698–2,706.

Ellis, M. M.
1937. Detection and measurement of stream pollution. Bull. U. S. Bur. Fish., Vol. 48, pp. 365–437.

Lang, R.
1925. Iodometrische Bestimmung con Cyanverbindungen. Zeit. Anal. Chem., Bd. 67, S. 1–15.

Schaut, George C.
1939. Fish catastrophes during droughts. Journ. Am. Water Works Assoc., Vol. 31, No. 5, pp. 771–822.

Schwarz, Robert and Karl Tede
1927. Uber die Photochemie der Komplexverbindungen. III: Die Hexacyanokomplexe des dreiwertigen Eisens, Kobalts, Chroms und Mangans. Ber. Deut. Chem. Gesell., Bd. 60, Ab. B, S. 69–72.

Part 11

Business Sessions

AMERICAN FISHERIES SOCIETY

Seventy-Eighth Annual Meeting

The seventy-eighth annual meeting of the Society was opened in the Haddon Hall Hotel, Atlantic City, New Jersey, at 10 a.m., Monday, September 13, 1948, with President H. H. MacKay in the Chair. The agenda were as follows:

Monday, September 13

Morning: Opening remarks of the President; reports of officers, standing committees and special committees; appointment of sessional committees.

Afternoon: Presentation and discussion of papers.

Tuesday, September 14

Morning and afternoon: Presentation and discussion of papers.

Wednesday, September 15

Morning: Panel discussion—Effectiveness of Present Fish-Management Practices on Inland Waters (joint meeting with the International Association of Game, Fish, and Conservation Commissioners).

Afternoon: Panel discussion—Major Problems of the Maritime Fisheries of North America (joint meeting with the International Association of Game, Fish, and Conservation Commissioners); reports of sessional committees; election of officers and installation of the new President; concluding business.

Evening: Annual Banquet—Vernon Room, Haddon Hall Hotel.

OPENING REMARKS OF THE PRESIDENT

H. H. MacKay

Ladies and gentlemen, as a Canadian I consider it a very great honor and pleasure to serve as President of the American Fisheries Society. In its behalf I extend a cordial welcome to the new members, to those who never fail to make the annual journey to the meetings and who represent the bulwark of the Society, and to our visitors.

Our host on this occasion is the New Jersey Department of Conservation. Col. Arthur F. Foran, Chairman of the Council of the Division of Fish and Game, is in charge of the local program and publicity arrangements. I should like to express to Col. Foran and his associates the thanks of this Society and our sincere appreciation of the excellent manner in which plans have been made for this convention in Atlantic City.

The first meeting of the Society was held at New York City, December 20, 1870. Its early founders recognized the need and importance of promoting the cause of fish culture, of gathering and diffusing information of a scientific character, and of uniting and encouraging those interested in fish culture and fishery problems. Throughout the years, these desirable objectives have been the guiding principles of the greatest value. Fortunately, the Society has been directed by persons who have had high standards of citizenship and high scientific attainments. "The importance of the practical affairs of life of abstract science, studied for its own sake, is often forgotten. The whole mechanism by which our civilization is held together is based on science. Our trains and motor cars, our medical science and our food supplies depend on discoveries made without thought for their practical application."

As of June 30, 1948, all classes of membership in the Society totaled 741. In this membership there are representatives of 45 states of the United States plus the District of Columbia and the Territories of Hawaii and Puerto Rico; 7 of the 10 provinces of Canada, including Newfoundland; Dominion of Canada representation; and representatives of Iceland, Brazil, Argentina, Mexico, Haiti, the Philippines, Australia, New Zealand, India, China, South Africa, England, Scotland, and Eire. The Secretary of the Society, and members generally, have done much to increase the membership, but greater concerted and organized effort is necessary.

During the interim between the Denver and Atlantic City meetings, two meetings of the Executive Committee were held, the first at St. Louis, March 8, 1948, and the second at Chicago, June 28, 1948. At the latter meeting Dr. John Van Oosten of the U. S. Fish and Wildlife Service, a former President of this Society, was chosen to represent us at the 10th Congress of the International Association of Limnology, Zurich, Switzerland, August 18–25, 1948. Mr. Kenneth A. Reid, Executive Director of the

Izaak Walton League of America, has charge of one section of the Inter-American Conference on Conservation of Renewable Natural Resources at Denver on September 16, and since Mr. Reid is also an active member of our Society he was appointed to represent our organization and also our provisional Western Division.

The special Program Committee appointed at the Denver meeting was most co-operative. Each member gave an expression of opinion regarding the program, and tentative plans, on which there was general agreement, were drawn up. In behalf of the Society I wish to convey to the Committee grateful thanks.

At the business meeting of the American Fisheries Society held at Denver, Colorado, September 12, 1947, a resolution was passed granting permission for the formation of a provisional Western Division of the Society and the incoming president was requested to name a chairman and an organization committee of five members to serve for one year or until appropriate provision was made in the Constitution and By-Laws, authorizing the establishment of a Western Division of the Society.

The establishment of a Western Division seems to be a logical evolution in the organization of the Society. There is need for much greater expansion in the field in which the Society operates and possibly a Western Division will be the answer to the problem, in so far as the western section of the United States and Canada is concerned.

Under the constitution of the Society as it now stands provision is made for five Vice-Presidents of the divisions of Fish Culture, Aquatic Biology and Physics, Commercial Fishing, Angling, and Protection and Legislation. In this way information regarding all lines of activities carried on by the Society is made available. In the past these reports have summarized so adequately trends of progress and advances in the field of fisheries that it seems unnecessary to include data of this nature in this report. It does seem desirable, however, to refer to a few of these developments. Problems concerning the scarcity of fish are common, and two of the commonest are: (1) what has happened to the fish; (2) what can be done about it?

The usual time-worn answers to these questions have given overfishing as the cause and restriction as the cure. However, it is good to note that now, increasing numbers of governmental and other agencies are careful to ascertain the facts before prescribing remedies. Much greater emphasis is being placed on the importance of suitable habitat or, if unsuitable, ways and means of improving it, or finding a better one. A few examples may be cited.

For many years fertilizers have been employed to increase the natural food supply in hatchery ponds in the United States and Canada. About 10 years ago two Alabama scientists, Swingle and Smith, who were studying methods of establishing farm fish ponds, noticed that ponds in rich agricultural land had a much greater growth of plankton and more and bigger fish than did ponds situated in less fertile land. They followed up their observations with experiments, and showed that by the addition of chemical

fertilizer to farm ponds the poundage of fish per acre could be greatly increased. Investigations of a somewhat similar nature have been conducted since then in many of the states and Canadian provinces.

Experiments on the removal by chemical treatment of undesirable fish from ponds and lakes, followed by rehabilitation of the waters through the introduction of desirable species, have been conducted by many workers during the past 25 years. A variety of chemicals including lime, copper sulphate, derris root (5 percent rotenone), and DDT have been used for this purpose. The literature contains many accounts of dramatic successes obtained by the use of this important management method.

The scarcity of salmon in a Nova Scotia river was attributed to commercial fishing operations, but Dr. Huntsman recently found that more salmon could be provided by a very simple device, namely, by providing freshets. After many preliminary studies, he selected for actual test a stream which the salmon ascended sometimes early in the season and sometimes late. Creation of a freshet caused them to move upstream early in the season, whenever they reached the mouth of the stream.

In the branch of statistics Van Oosten and Hile have done commendable work. Ricker's studies of fish populations in fresh water and Merriman's in coastal waters have provided knowledge of inestimable value. Valuable information on yields and composition of annual catches of fish has been supplied by many investigators in both Canada and the United States.

As a result of biological surveys, many non-producing lakes in Alberta's Banff Park have been stocked with suitable game fish and are now productive. Plantings have been made also to many formerly fishless lakes in the mountain areas of British Columbia. The Fisheries Research Board of Canada has conducted surveys of lakes in the Northwest Territories of Canada to determine the advantage or disadvantage of opening these lakes to commercial fishing. Surveys in Michigan, Ohio, New York, and elsewhere, have been the means of developing interesting fish-management programs.

The foregoing are but a few examples of how fact-finding programs are leading to more efficient management of North American fisheries, and conclude the remarks I wish to make at this time.

APPOINTMENT OF SESSIONAL COMMITTEES

Time and Place

O. Lloyd Meehean, District of Columbia, *Chairman*
W. J. K. Harkness, Ontario
Alan C. Taft, California
Marion Toole, Texas
C. R. Gutermuth, District of Columbia

Resolutions

H. J. Deason, District of Columbia, *Chairman*
Fred A. Westerman, Michigan
Alan C. Taft, California
Ralph Hile, Michigan
James N. Gowanloch, Louisiana

Nominations

Stillman Wright, District of Columbia, *Chairman*
Edward Schneberger, Wisconsin
Fred A. Thompson, New Mexico
I. T. Bode, Missouri
John R. Greeley, New York

Auditing

Eugene W. Surber, West Virginia, *Chairman*
A. D. Aldrich, Oklahoma
M. F. Clark, Kentucky

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

RUSSELL P. HUNTER

Membership, Publications, and Financial Status.—Statistics on the various classes of Society membership are presented to permit comparison of figures for 1947 and 1948:

Type of Membership	*1946–47*	*1947–48*
Active	653	669
Club	21	21
Life	27	27
Library	47	45
Honorary	6	11
State	33	33

As announced in the letter sent to members in advance of the meeting Volume 74 of the TRANSACTIONS for 1944 has been completed and sent out to the membership. Volume 75 is near completion and will probably be mailed to members by the end of the present month.

The list of common and scientific names of fishes prepared by the committee headed by Mr. Chute has been published and mailed to the membership. The extra copies of this edition of 4,000 have been sent to Dr. William C. Beckman, Acting Librarian, at Ann Arbor, Michigan.

A letter vote of the Executive Committee authorized the Secretary to execute a contract with the Craft Press at Ann Arbor for the printing of Volume 76 under the supervision of Dr. Ralph Hile, the Chairman of the Editorial Board. This contract for 1,000 volumes at approximately $4 each is more expensive than previous contracts, but the Committee felt that the selection of a printer conveniently located for the Chairman of the Editorial Board might be of assistance in bringing our publication schedule up to date. A contract for the printing of Volume 77 has also been authorized by the Executive Committee, but as yet it has not been executed.

No expenditures have been made from the Permanent Fund to meet printing bills during the current year, although such expenditures were authorized at the Denver meeting. The Permanent Fund will probably be drawn upon to pay accounts this year. The Society should give consideration to an increase in dues at this meeting.

Formation of a Western Division.—On June 2 a meeting of the provisional Western Division of the AMERICAN FISHERIES SOCIETY was held at the Newhouse Hotel, Salt Lake City, Utah. Twenty-three men were

present. Tentative plans for organization were drawn up and the following officers were elected:

President: Paul R. Needham, Portland, Oregon
Vice-President: John L. Hart, Nanaimo, British Columbia
Secretary: Fred A. Thompson, Santa Fe, New Mexico

Resignation of the Librarian.—Mr. Kenneth E. Cobb, who has served the Society as Librarian for many years, submitted his resignation last year. No successor could be elected until suitable arrangements could be made for the storage of over 3,000 volumes of the TRANSACTIONS. Dr. William C. Beckman, the Institute for Fisheries Research, Ann Arbor, Michigan, has now completed such arrangements and the volumes will be shipped to him. Mr. Cobb's resignation may now take effect, and the Society may elect Dr. Beckman as his successor.

Meeting of the Executive Committee.—A joint meeting of the Executive Committees of the American Fisheries Society and the International Association of Game, Fish, and Conservation Commissioners was held on June 28, 1948, in Chicago, Illinois, at the Illinois Athletic Club, where those in attendance were entertained as guests of Commissioner Osborne of Illinois.

Committee members and other members of the Society present at this meeting were: President H. H. MacKay, First Vice-President Seth Gordon, Second Vice-President A. S. Hazzard, Secretary-Treasurer R. P. Hunter, Lester Bagley, Arthur Foran, W. J. K. Harkness, O. R. Kingsbury, L. Osborne, and H. A. Rider.

The meeting was called jointly by the presidents of the two organizations, with the aim of planning details for the Atlantic City meeting.

REPORT OF THE DIVISION OF FISH CULTURE

O. R. KINGSBURY

Fish-culturists have met the demand for increased production throughout North America since the war. Many fish hatcheries have produced more pounds of fish with their old, unchanged facilities than their fondest hopes ever anticipated. Many hatcheries have been expanded in order to produce more fish, particularly legal-sized trout, and they also have exceeded their contemplated output. Satisfactory criteria by which the efficiency and the maximum producing capacity of a hatchery can be established are of the utmost importance.

The aim of fish culture is to increase production and decrease operating expenses while maintaining the quality of the product and meeting the stocking needs in the area served. These objectives can be attained in various ways. If production is increased and the expense remains constant, the objective has been accomplished. If, by expansion in pond space and the employment of new techniques, the production has been substantially

increased at only a small increase in cost in operating expense, the objective has been accomplished. Therefore, it behooves today's fish-culturist to report on his techniques, hatchery design, new equipment, and general hatchery management which result in more efficient management of a hatchery unit. *The Progressive Fish-Culturist,* published by the U. S. Fish and Wildlife Service welcomes contributions for current publication on the subject.

Many factors are involved in measuring the productiveness of a trout hatchery. All fish-culturists realize that the available flow and the temperature of water and the amount of available rearing space are of the utmost importance. These items have a direct relationship with the design of the hatchery; the ease with which a unit can be operated has a tremendous influence on labor and maintenance costs.

I wish to present to you production figures on three of our New York State trout hatcheries, which illustrate the influence on hatchery production at the flow of water in gallons per minute, the cubic feet of rearing space, and water temperature.

The Bath Hatchery was remodeled before the war. Sixteen rearing ponds, having a capacity of 1,250 cubic feet each when operated at a depth of 2 feet, together with 84 outside rearing troughs and 56 inside hatching troughs, comprise the available production space of 21,134 cubic feet. Two water sources, one a spring and the other a spring brook, supply a total summer flow of 1,050 gallons per minute. The temperature range of the water is 44.1° F. to 53.4° F.

In our fiscal year 1943–44, this hatchery produced 27,000 pounds of trout at a cost of approximately $0.80 a pound. For each cubic foot of space, 1.25 pounds of trout were produced, or 25 pounds for each gallon-per-minute flow. During the corresponding period of 1946–47, production reached 44,139 pounds at a cost of approximately $0.72 per pound. For each cubic foot of rearing capacity, an average of 2.1 pounds of trout was produced, or 42 pounds for each gallon-per-minute flow for the period. This increase in productivity—17,139 pounds at a cost reduced by 8 cents per pound, even though operating cost had greatly increased—was accomplished by earlier feeding of fry and utilization of the rearing ponds in April for fish of the year. The preparation of the diet and the resulting reduction in pollution from feeding had a pronounced effect on the efficiency of the unit.

Up to 1946 the Warrensburg Hatchery had a rearing capacity of 1,847 cubic feet, made up of 40 hatching troughs, 15 outside rearing troughs and 9 rearing ponds or raceways. The water supply is made up of springs furnishing a flow of 339 gallons per minute in the summer months with a temperature range of 44.9° F. to 53.3° F. During the fiscal year 1943–44, the hatchery produced 4,891 pounds of trout, or 2.62 pounds for each cubic foot of space and 14.25 pounds per gallon of flow.

In 1946, the hatchery was remodeled. Three of the raceways were discarded and six circular ponds were put into operation. The rearing capacity

now is 4,400 cubic feet as compared with the previous 1,847 cubic feet.

During the period 1947–48, the Warrensburg Hatchery produced 13,482 pounds of trout, an increase of 8,591 pounds. This production represented 3.07 pounds produced for each cubic foot of rearing space, or 40 pounds per gallon of flow. As a result of the increased production, a saving of 43 percent was realized. Perhaps the efficiency of the unit can be increased by the future addition of one more pond.

The Cold Spring Harbor Hatchery was established in 1880. It is a striking example of what a modern trout hatchery should not be. The rearing raceways and stock ponds are constructed in a series—one long chain of 44 ponds. These ponds, together with 30 inside hatching troughs, have a total capacity of 69,053 cubic feet. The water supply, approximately 410 gallons per minute, comes from a small spring pond and two artesian wells. The temperatures vary greatly from the various sources; perhaps an average range of 40° F. to 60° F. would be a fair figure. During the fiscal year 1943–44, 3,937 pounds of trout were produced at a rate of 0.06 pound for each cubic foot of rearing space, or 9.6 pounds for each gallon per minute flow. In 1947–48, a production of 13,693 pounds was attained, an increase of 8,756 pounds or approximately 222 percent, for a saving of 51 percent over the earlier period in operating costs. The figures on pounds per cubic foot and per gallon per minute of flow were 0.198 and 27.4 respectively. This increase was accomplished by the elimination of all brood stock, the use of a disease-resistant strain of fingerlings, the use of sulfadiazine in disease control and the replacement of the two old artesian wells with two new wells. Future plans for this hatchery call for a new design to bring the flow and the rearing capacity into a proper relationship.

Temperatures as well as volume of flow have a pronounced effect on the production of a trout hatchery. The Bath and Warrensburg hatcheries have approximately identical operating temperatures. The volume of flow at Warrensburg is 711 gallons less than at Bath. The distance that the water is exposed before use is greater at Bath than at Warrensburg but the greater flow at Bath prevents an excessive cooling or warming of the water. At the Cold Spring Harbor unit, the temperature of water from the wells is constant and only small fluctuations occur in the spring pond. However, the surface area that is exposed, approximately 34,500 square feet, results in a wide fluctuation in operating temperatures with the flow of 410 gallons per minute. When Warrensburg was remodeled to conform with Bath, it yielded 40 pounds for each gallon per minute of flow. The proposed redesigning of Cold Spring Harbor should accomplish a similar result. It is possible that in the future increased knowledge will permit increased expansion, and thus raise the pounds produced in relation to the gallons of flow. It must be borne in mind that an increase in pounds of fish produced in a given hatchery results in a reduction in operating costs. The available flow, therefore, has an effect not only on the units it is possible to produce, but also on the cost of operation.

It would seem that the productiveness in fish hatcheries can best be

measured by the pounds produced per cubic foot of rearing space and the pounds produced per gallon of flow per minute. The maximum poundage that it is possible to produce per gallon per minute of flow at a given temperature has not been established. It is sincerely hoped that all fish-culturists will give this means of evaluating productivity careful consideration so that our combined endeavors will result in the establishment of a more secure foundation for future fish-cultural operation.

REPORT OF THE DIVISION OF AQUATIC BIOLOGY AND PHYSICS

Paul R. Needham

Since this meeting may be the "swan song" of such divisions as Aquatic Biology and Physics, I feel impelled to report in all truthfulness that the elimination of these subdivisions should benefit the Society. Although they have given the divisional Vice-President a fine chance to be heard and while much good information has been presented from time to time, it is information of a type that could have been better presented in the regular papers.

If there is any value in brevity, the palm should certainly go to the writer of one report for this division who presented 17 lines of text exclusive of the title and the name of the author. I cannot hope to better this record because the items I intend to discuss, however briefly, will require somewhat more space. These items are: public education in relation to research and stocking policies; the use of insecticides and herbicides in water; and fishery-protection problems in relation to dams.

Need for Better Public Information on Research and Stocking.—Much better and more effective research might be accomplished if the state conservation departments were able to utilize more fully the facilities provided by their state universities. In some states there are excellent cooperative arrangements in effect but in many collaboration is scant. It would strengthen the efforts of state fish and game administrators considerably if they used more widely the talent available in their educational institutions. The professor and the game administrator should get together; they would learn much from each other. In the field of game research, the Pittman-Robertson units furnish an excellent example of cooperative research. Possibly the Dingell bill will give us parallel opportunities in fisheries.

Many state administrators still have little confidence that research will aid in the solution of their fishery problems. To cite an example: research on the survival of hatchery-reared fish has already demonstrated where and when artificial propagation fails and where it helps. Yet today "blind" planting of expensive hatchery fish continues in spite of knowledge which, if applied, would result in the saving of thousands of dollars annually. It has always been hard to bring about the application of research to management

programs. The basic difficulty here has been one of getting the facts before the angling public. We must come to recognize that public information is of paramount importance. The public must understand the results of stocking, its costs and its wastes. The all-consuming faith in fish hatcheries by the public and by some conservation officials who refuse to recognize the facts is a great obstacle to fishery management today. Once the angling public understands the economics of hatcheries, it will demand drastic changes in present programs. We know that hatcheries are always going to be needed; the real question is how best to use the products of hatcheries.

The biologist has been considerably at fault in our failure to inform the public. Frequently he does not present the results of his work in clear, readable form. He often fails also to present his facts promptly, so that they can be applied immediately in management programs. Caution is an admirable quality in a researcher, but all too often the desire to close the last loophole and control the last variable results in unjustified delay. It should be remembered that the administrators control the budgets; to obtain their confidences and support the biologist must see that any fact or any bit of information be made immediately available to those who apply them. We need popular accounts for general consumption that will lead our public to the correct understanding of our problems. Once the public does understand our problem, it will be less prone to criticize and will be more willing to support our work.

Research has clearly indicated that the planting of legal-sized fish will produce good angling in intensively fished waters, but money is required to pay rearing and planting costs. Instead of paying for the rearing and distribution of legal-sized fish from the general license funds as we have been doing, perhaps we should stock these fish only in streams and lakes set aside as public fishing areas and where a small fee paid by each angler will meet all costs. Thus those who catch the fish would pay for them. In other waters both cold and warm, natural reproduction can be depended upon to provide the best fishing obtainable for those who do not care to catch legal-sized hatchery-reared fish.

Along with our hatchery program, lake fertilization and habitat improvement can be counted upon to carry a major share of the load. These procedures, in combination with adequate fishing regulations based on facts and in accordance with the habits of the species concerned, can lead to improved angling. Improvement of spawning beds in trout waters remains a largely unexplored field and one which I am confident, once an adequate amount of experimental work is completed, can do much toward the maintenance of fish populations by aiding natural propagation.

Use of Insecticides and Herbicides in Water.—Within the past few years, rapid strides have been made by American chemical companies in the development of poisons for the control of water-dwelling plant and animal pests. These substances, such as DDT, 2,4-D, and others, to a large extent have been used blindly by municipalities and other public agencies and without knowledge as to their ultimate effect on the basic ecology of

waters treated. The use of copper sulphate, for instance, in the control of algae and other aquatic plants is not new by any means, and the long-term effects of repeated introductions of this substance have clearly indicated the inadvisability of regular annual application. Waters thus treated frequently become poor producers of fish and deteriorate into aquatic deserts. The long-term results of the rotenone, 2,4-D, DDT, and other pest-control substances has not been measured and there are but scant data available upon which to base any prediction of their final effects. Certainly the fishery-research agencies concerned should attack this problem seriously lest we find some day that we have ruined many formerly productive waters.

Fishery-Protection Problems in Relation to Dam Construction.—Water-development programs and fishery-protection problems are of vast importance, particularly to the states. Government engineers intent upon the creation of a huge network of hydro-electric, flood-control, irrigation, and navigation projects in every single major stream in the West will, if funds are provided, completely change aquatic conditions in western America as we know them today. Over 200 dams, for instance, are being contemplated for the Columbia River and its tributaries alone. Some 20 dam sites are under study in the Rogue River Basin. The Sacramento-San Joaquin River systems in California are being developed on a parallel scale, while to the east, the Colorado, Missouri, Platte and other streams are to be developed to their maximum in the creation of huge "inland empires." Whether or not these mammoth projects are sound in terms of costs and benefits is a problem for the economists, but their effect on our aquatic resources is our problem. In the Columbia River, steelhead trout and salmon runs worth over 20 million dollars annually are being jeopardized and will be lost if present plans go through. Both state and federal fishery officials have been actively working to have the upstream dams constructed first to avoid blocking of anadromous fish runs in lower waters. But the voice of the fishery interests is low and heard only faintly above the uproar of the advocates of flood control, power, irrigation, and navigation. We are not opposing dams blindly; all we want is a fair consideration of all values and to date we have not had it. Public Law 732 now requires that studies of wildlife and fishery values must parallel engineering studies for the dams but this law does not go far enough. We need a thorough, unbiased analysis of each project in terms of all values concerned. The constructing agencies cannot be said to be unbiased in their recommendations. A separate board of experts in each field concerned should be established to review each project, and its members should not be paid by the constructing agencies. Only when this type of arrangement has been made shall we get decisions based on the real facts. Possibly the proposed reorganization of government departments may produce such boards but established thinking of personnel of the departments concerned will strongly oppose any such change. A resolution by the Society in this matter would do much good in bringing pressure to bear for the appointment of such boards.

REPORT OF THE DIVISION OF COMMERCIAL FISHING

A. W. Anderson

The catch of fish and shellfish in the United States and Alaska was about 4½ billion pounds in 1947, or about the same as the average annual catches from 1935 to 1939. The composition of the catch in recent years has differed greatly, however, from the pre-war pattern. Landings of menhaden last year, for example, were the greatest on record and constituted our largest single fishery. The former leader in volume, pilchards, dropped to the smallest catch in 20 years. Salmon production has been well below the pre-war average with the diminishing catch causing much concern. Maine sardines have had a series of years of large production while the tuna pack has reached a new record total. The pack of canned mackerel also has been considerable.

Fish-meal and oil production has held up well despite the decline in the pilchard catch. Freezings of fishery products and holdings also are at high levels but have not surpassed the peak year of 1946. Imports of frozen fillets may equal or surpass the 1946 record of about five times the pre-war figure. Fishing vessels are continuing to be documented in large numbers. In 1947 the rate was over four times the pre-war average.

In foreign countries, particularly Europe, catches are at or near normal in most areas despite difficulties of foreign exchange, transport, . . . The international export and import pattern is shifting to meet altered conditions and probably will not approach stabilization for a considerable period. A number of the European countries are acquiring increased fleets of modern trawlers. The impact of these new vessels on established fisheries and markets has not yet been felt to any great degree.

Fishery research, particularly oceanic research, has been favored in the last year. A Pacific Oceanic Fishery Investigation has been started by the U. S. Fish and Wildlife Service. With a biological and oceanographical vessel and two exploratory fishing vessels, the Service will conduct exploratory fishing and developmental work in the tropical and subtropical waters of the Pacific from Hawaii westward. Honolulu will be the base of the vessels and the site of the Service laboratory for biological, technological, and exploratory fishing activities. The tuna industry, in both Hawaii and on the Pacific coast, has evinced great interest in the tuna resources of the Southwest Pacific.

The Fish and Wildlife Service also sent to northern waters in August a 100-foot exploratory fishing vessel. This vessel, the *Washington,* has begun 2 months of exploratory fishing in the offshore waters of the Bering Sea to determine additional fishery possibilities existing in that area. After necessary changes have been made in the vessel during the winter to adapt it better to exploratory fishing it will continue this type of activity in the Alaskan area. Because of the curtailed seasons for halibut and salmon in Alaska there is much interest in the development of fisheries which will reduce the strain on the major species. The fishery for king crab, stimu-

lated by the Service's exploratory fishing immediately before the war, is increasing steadily. Commercial ventures have already demonstrated that king crabs can be caught and processed satisfactorily. Incidentally, they have also confirmed the Service's report of the large volume of bottom fishes available.

The *Albatross III*, a Service vessel designed especially for biological and oceanographic research, began work in North Atlantic waters in March. It operates from an expanded laboratory at Woods Hole.

The Fish and Wildlife Service has had in progress for 2 years a program to assist the Philippine Government to rehabilitate its fisheries. Three vessels of varying sizes and design are available to conduct research and exploratory fishing in Philippine waters, and a staff of United States and Filipino research workers is housed in a laboratory in Manila. This program is scheduled, at present, to end in 1950.

Other important oceanic research programs besides those mentioned including research of the International Commissions regulating the halibut and sockeye salmon fisheries are beginning or are in progress. For example, the salmon industry and the University of Washington have been cooperating on a salmon study in Alaska. The pilchard industry, the State of California, and the University of California are beginning a comprehensive pilchard investigation. The State of California also has been working actively on tuna and recently sent a research vessel as far as Hawaii.

Cooperation among the states in fishery matters has taken a long step forward with the formation of Marine Fisheries Commissions under authority of Congress. The Atlantic States Marine Fisheries Commission has been active for a number of years. The Pacific States Fisheries Commission, recently established, has had several meetings and has prepared an interesting summary of the status of the various Pacific coast fisheries, the problems encountered, and recommendations for solving them. Formation of a Gulf States Marine Fisheries Commission has been favorably discussed in Congress but approval, unfortunately, was not forthcoming at the last session.

Internationally, fishery matters are now the concern of at least two United Nations organizations. The Food and Agriculture Organization has a fishery division subdivided into biological, technological, and economic sections. Currently, it is interested in such matters as the development of regional councils in various areas throughout the world for the purpose of exploring the sea. The first such council was discussed at a conference in the Philippines in February 1948, and will probably result in the formation of an Indo-Pacific Fisheries Council before the end of 1948. FAO's fisheries division also is making an economic study of the salt-fish industry and has made inquiry as to the need for international standards for certain fishery products. FAO's fisheries staff and fisheries budget, although both small, can be of very great help to many countries in the development of their fisheries, and the resulting attainment of one of FAO's objectives—raising the standard of living.

Although the International Trade Organization is still on an interim basis,

its charter embraces trade in fishery products and may have considerable effect on our fisheries whenever enough nations accept its provisions so that they go into effect. Fishery treaties or agreements, so long as they are made purely for conservation purposes, are exempted from ITO regulations. If they contain provisions, however, which regulate trade in fish or in fishery products, they must conform to ITO trade practices.

From a technological viewpoint the fishing industry is making advances and apparently is on the threshold of developments which may have important effects on large segments of the industry. Synthetic vitamin A is threatening the vitamin-oil industry based on fish livers but much research is being conducted on by-products to develop other valuable materials of a pharmaceutical nature. A method of inhibiting enzymatic and bacterial action in fishery products without changing the character of the products has received some publicity and the attention of an important foreign fish-producing country. Presumably it is still in the experimental stage but promising. Possibly the most spectacular development is the utilization of refrigerated carriers of a thousand tons or more to receive catches of domestic fishing craft in distant foreign waters. This practice, as carried on off Central America by carriers operating from as far away as Oregon, has opened new grounds to fishing craft of limited range and capacity, has provided canneries with more uniform supplies of fish, and may be the means by which any nation can fish in any waters of any ocean.

REPORTS OF STANDING COMMITTEES

COMMITTEE ON INTERNATIONAL RELATIONS [1]

James N. Gowanloch

Cooperation with American Republics

The Interdepartmental Committee on Scientific and Cultural Cooperation was created by the President in May 1938 to facilitate the solution of problems of common interest to the peoples of the American Republics. The Congress, through enactments in 1939, authorized the conduct of cooperative programs and the exchange of technical specialists. The program of the Committee, financed by the annual Department of State appropriation, "Cooperation with American Republics," and carried out by numerous Federal agencies, is a practical, realistic plan of cooperative action through exchange of information, skills, and knowledge which will assist in intellectual growth, in the spread of information and techniques, in the handling of social and economic problems, and in the increase of understanding among peoples.

Mexican fishery mission.—Continuation of the fishery mission to Mexico in the fiscal year 1948, with Mr. Milton J. Lindner as Chief of Mission, was fully justified by the outstanding success of the mission in earlier years. Mexico and the United States have many fishery interests and problems in common, both in the Gulf of Mexico and along the Pacific Coast. It is well known that roughly three-fourths of the Mexican catch of fishery products and those taken off the Mexican coasts are exported to the United States or transported there in American fishing vessels.

Because of these common interests, it is the function of the Mexican fishery mission to assist both countries to uncover facts pertaining to the little-known resources of Mexico, to assist Mexico in training a competent staff of fishery investigators, and to bring about a better understanding and closer cooperation between the two countries with respect to the conservation and optimum utilization of the fisheries. The mission performed these functions with outstanding success during the year just ended.

Fishery mission to Venezuela.—As a direct outgrowth of a mission to study the salt-fish industry of Venezuela in 1943, the Venezuelan Government in 1947 requested the active cooperation of the Fish and Wildlife Service in a more extensive and long-continued survey. Accordingly, Mr. Robert O. Smith was assigned early in 1948 to a year-long investigation of

[1] I wish to acknowledge the assistance of the several committee members and of others in the preparation of this report. I am especially grateful to: H. J. Deason, Chief, Office of Foreign Activities, Fish and Wildlife Service; H. A. Dunlop, Director, International Halibut Fisheries Commission; and B. N. Brennan, Director, International Pacific Salmon Fisheries Commission.

the marine fisheries of that country. All expenses of the survey will be met by the Government of Venezuela. To facilitate the investigation, the Government of Venezuela purchased a vessel in the United States and fitted it especially for the purpose of experimental fishing. Although the study will be directed at a diversity of forms, including shrimp, Spanish mackerel, bonito, tuna, pompanos, bluefish, flounders, snappers, and groupers, special attention will be given to the sardine.

Fishery mission to Panama.—At the request of the Government of Panama, the Fish and Wildlife Service in January 1948 assigned Dr. Paul S. Galtsoff to an investigation of the pearl-oyster resources of Panama. All costs of the study were borne by the Panamanian Government. For some time there has been a decline in the pearl-oyster industry, and it is generally believed that the oysters have been adversely affected by disease. Dr. Galtsoff made an exhaustive inquiry over a period of two months into all physical, chemical, and biological factors which may influence the oysters. Prior to his return to the United States, he made a brief visit to Venezuela to conduct a preliminary survey of the oyster resources of the Hargarita region.

In-service training grants.—During the fiscal year 1948, the Fish and Wildlife Service continued its program of in-service training grants which provides opportunities to qualified students from American republics to receive training and experience in several phases of fishery science and wildlife management. Grants are being offered in fish culture, fishery biology, aquiculture, fishery economics, fishery technology, management of injurious wildlife, wildlife conservation and management, and fur-resource technology. Ordinarily, the training period covers one year. During the fiscal year 1948, 10 students were in training in the United States: 2 each from Brazil, Uruguay, and Peru: one each from Venezuela, Costa Rica, Bolivia, and Argentina. The training program is a valuable adjunct of the mission program, for it provides an increasing group of technically competent persons to assume responsibility in connection with the development of plans founded upon the mission investigations.

Grants-in-aid to specialists.—A program which promises to be of great importance is that of grants-in-aid to persons of mature training and experience in fish and wildlife conservation. The grants are usually for 3 months, and may be made to specialists of the United States for visits to other American Republics, or to those of other Republics for visits to this country. In the current year, grants were made to: Mr. Fernando Obregon, of Mexico; Dr. E. H. Cordero, of Uruguay; and Dr. A. G. da Silva, of Brazil. Grantees from other countries visit a wide variety of American institutions concerned with the conservation of fish and wildlife, to learn as much as possible about conservation problems and what is being done to solve them. At appropriate times and places, they present similar information about their own country. The plan thus makes possible an interchange of information and ideas which is of value to both of the participating countries, as well as to the grantee.

Rehabilitation of Philippine Fisheries

The only project under the Philippine Rehabilitation Program concerned with food supply and production is the fishery rehabilitation and development program undertaken by the Fish and Wildlife Service. The project is designed to provide—through research, experimentation, and demonstration—fundamental scientific and economic information upon the basis of which the Philippine fishing industry may be restored, modernized, and expanded.

The program is concerned with fundamental investigations and experimentation in oceanography, fishery biology, ecology, and exploratory fishing to determine the commercial practicability of conducting operations in various areas, the best type of gear for exploitation of the resources in such areas, and modifications or improvements in existing fishing practices in order to provide for better utilization of the resources. Simultaneously with the foregoing, there are being conducted: studies of handling, dressing, and storing catches on shipboard and at shore fishery establishments; experiments in the freezing, smoking, salting, canning, and other processing of fishery products; studies and pilot-plant experiments in the preparation of fishery by-products such as industrial and vitamin oils, and shark hides for leather; and studies of the management of brackish and fresh-water fish ponds, with a view toward promoting greater production and efficiency. The fishery exploration and research at sea is accomplished by three vessels: a combined oceanographic vessel and tuna clipper; an experimental purse seiner and trawler; and a small demonstratoin vessel manned by Filipinos.

The inshore fisheries, now exploited to the maximum, will never meet local requirements fully, and it is essential to the future economy of the Philippines that new exportable commodities be produced. It is expected that the deep-sea fisheries will provide both the additional food for local consumption and an exportable excess. Records of Japanese fishery operations on the high seas adjacent to the Philippines indicate that they caught quantities of tuna, bonito, and other pelagic fishes suitable for canning and the manufacture of by-products.

The pondfish industry of the Philippines, where salt-water species are impounded and reared to marketable size in a fraction of the time required in the open sea, offers great possibilities for expansion and greater production through modernization. With the cooperation of the Philippine Bureau of Fisheries, an extensive experimental program is underway involving the use of modern excavation machinery, up-to-date hatchery and pond-fertilization techniques, and the training of skilled operators.

The Philippine Rehabilitation Act authorized the training in the United States of not more than 125 Filipinos in numerous phases of fishery science and industry. The objective of this program is to provide a group of competent specialists to assist in the rehabilitation and further development of the Philippine fisheries. The training period is one year for each student. The first group, composed of 21 trainees, arrived in the United States in

April 1947 and returned in May 1948. The second group, consisting of 22 students, arrived in November 1947; and the third, of 18 students, arrived in June 1948.

The training is of two general types: practical instructions in the fishing and allied industries, and theoretical and practical instruction in colleges, universities, and in laboratories of the Fish and Wildlife Service. All trainees take an initial intensive course of 5 weeks in subjects concerned with seamanship at the United States Maritime School, Alameda, California.

Following this general training period, those who are to study the practical phases of the fishery industry are assigned to ports in various sections of the country, where they learn by engaging in routine fishing operations. In addition, they work at shore stations to gain proficiency in processing methods such as filleting, refrigerating, smoking, salting, curing and canning. They also receive training in the construction and repair of nets, boats, and marine engines and associated equipment. In short, the program provides for practical instruction by actual participation in the numerous operations of the industry. However, the students receive no remuneration for services rendered, and they do not replace workers who regularly perform such services.

Great Lakes Fishery Treaty

During the sessions of the 80th Congress, the Senate took no action on ratification of the United States-Canadian Great Lakes Fishery Treaty.

Proposed United States-Mexican Fishery Treaty

The many international problems and controversies, major and minor, that have arisen in connection with United States and Mexican fishing enterprises in the Gulf of Mexico and off the west coast of Mexico have led to the conclusion that an international fishery treaty is desirable. During the past three years the Fish and Wildlife Service has been collaborating with the Department of State in drafting proposals for a treaty, in preparing background material, and in holding consultations with representatives of state conservation departments and of the fishing industry. The valuable tuna fisheries off the west coast of the United States and Mexico and the extremely important shrimp and red snapper fisheries in the Gulf of Mexico would be effectively conserved, and when necessary regulated under the proposed international arrangement.

Proposed Northwestern Atlantic Fishery Treaty

Popular interest has developed in a treaty that will provide for international regulation and management of the fishery resources of the Northwestern Atlantic Ocean. Signs of diminution in the New England fisheries and the increasing magnitude of operations on the Nova Scotia Banks and

the Grand Banks of Newfoundland by vessels of European nations have given rise to popular interest in such a convention by the United States and Canada. Many informal conversations of Federal and State officials with regard to such a treaty have been held during recent years, and work toward a treaty has been intensified during the past year. The United States, Canada, Newfoundland, and France have major interest in such a treaty, since they have territorial interests in the Northwestern Atlantic, but certain European nations have historical fishing rights in the area and should participate in the proposed international agreement.

Fishery Activities of the Food and Agricultural Organization of the United Nations

The Food and Agricultural Organization was established in Quebec in October 1945 to contribute to an expanding world economy by raising levels of nutrition and standards of living, improving the production and distribution of food and agricultural products, and bettering the conditions of rural populations. The Fisheries Division is organized into three branches: Economics and Statistics, Technology, and Biology.

Fishery interests of the United States are represented at FAO meetings by membership on the United States delegation of an officer of the Fish and Wildlife Service. The meeting at Geneva in autumn of 1947 approved two types of work for immediate action: formation of Regional Councils for scientific exploration of the sea; and adoption of international standards of quality, packaging, weights, and descriptions. Attention was called to the need for commodity studies similar to that represented by the recently completed report on salted fish.

Indo-Pacific Council

Delegations of countries interested in the fisheries of the far western Pacific and Indian Oceans met at Baguio, Philippines, in February 1940 where they drafted and resolved to recommend to their governments the approval of an agreement which establishes the Indo-Pacific Fisheries Council. The council will be composed of members from each adhering government and the secretariat will be provided by the Food and Agricultural Organization. The council will be established when five nations have approved the agreement, which lays down a comprehensive program that is expected to aid greatly the development and proper utilization of the fishery resources of the area.

United Nations Conference on Trade and Employment

The United Nations Conference on Trade and Employment which had been in session in Havana since November recently concluded its efforts to establish an International Trade Organization with the signing of the Final Act by more than 50 representatives of governments present. The

Charter now goes to the governments for consideration and acceptance. When accepted by a majority of the signatory governments, or by 20 governments after one year, the Organization will come into being. Meanwhile an Interim Commission will function.

The objectives of the ITC are as follows:

1. To assure a large and steadily growing volume of real income and effective demand, to increase the production, consumption and exchange of goods, and thus to contribute to a balanced and expanding world economy.
2. To foster and assist industrial and general economic development, particularly of those countries which are still in the early stages of industrial development, and to encourage the international flow of capital for productive investment.
3. To further the enjoyment by all countries, on equal terms, of access to the markets, products, and productive facilities which are needed for their economic prosperity and development.
4. To promote on a reciprocal and mutually advantageous basis the reduction of tariffs and other barriers to trade and the elimination of discriminatory treatment in international commerce.
5. To enable countries, by increasing the opportunities for their trade and economic development to abstain from measures which would disrupt world commerce, reduce productive employment, or retard economic progress.
6. To facilitate through the promotion of mutual understanding, consultation, and cooperation, the solution of problems relating to international trade in the fields of employment, economic development, commercial policy, business practices, and commodity policy.

Originally the New York draft of the proposed ITO Charter exempted fishery conservation agreements from ITO regulations and supervision. Later, at Geneva, the exemption was removed so that such agreements would have had to meet all ITO requirements. As a result they might have been delayed for years or even blocked altogether because the ITO Charter is designed primarily with *trade* agreements in mind and not *conservation* agreements.

At Havana, however, through representation by the Department of the Interior, Article 67 in Chapter VI—Intergovernmental Commodity Agreements—was amended to read as follows:

(d) . . . . to any inter-governmental agreement relating solely to the conservation of fisheries resources, migratory birds and wild animals; Provided that such agreements are not used to accomplish results inconsistent with the objectives of this Charter and are given full publicity in accordance with the provisions of Article 57, paragraph 1 (e), and that if the Organization finds, upon complaint of a non-participating Member, that the interests of that Member are seriously prejudiced by the agreement, the agreement shall become subject to such provisions of this Chapter as the Organization may prescribe.

At the same time Article 43 in Chapter IV—Commercial Policy—was amended to read as follows:

1. Subject to the requirements that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between Member countries where the same conditions prevail, or a disguised restriction on international trade, nothing in this Chapter shall be construed to prevent the adoption or enforcement by any Member of measures.

(x) . . . . taken in pursuance of any inter-governmental agreement which relates solely to the conservation of fisheries resources, migratory birds or wild animals and which is the subject of the requirements of paragraph 1 (d) of Article 67.

Conseil Permanent International pour l' Exploration de la Mer

The Conseil Permanent International pour l'Exploration de la Mer will meet in Copenhagen, Denmark, October 5–11. The United States has been invited to send observers to the meeting. One representative of the Department of State and one of the Fish and Wildlife Service will attend.

Arctic Expeditions

During the summers of 1946, 1947, and 1948, upon invitation of the Secretary of the Navy, the Fish and Wildlife Service assigned observers to accompany Arctic expeditions of the Navy. They have obtained valuable data on the fauna of Arctic waters and islands.

United States Whaling

The Secretary of the Interior, through the Fish and Wildlife Service, is responsible for the licensing of United States whaling enterprises, and for the conduct of biological and statistical investigations required under the terms of international agreements for the regulation of whaling. Only one whaling station was licensed in 1948. A biologist was in residence during the season to obtain biological data on the whales captured and processed, and to make observations on the abundance and movements of the whale populations.

The Fish and Wildlife Service has continued the analysis of data and preparation of reports on Japanese whaling operations since 1939, as required by international agreement, since the Japanese Government failed to meet that obligation.

New International Convention for the Regulation of Whaling

An International Whaling Conference convened in Washington in 1946, and drew up two international agreements: (1) A Protocol for the Regulation of Whaling, effective only for the 1947–1948 whaling season, and (2) an International Convention for the Regulation of Whaling, which replaces former basic international whaling agreements, as amended, and becomes effective for the 1948–1949 and subsequent seasons. The Convention provides for the establishment of an International Whaling Commission, which is empowered to make changes in the regulations from time to time. It is expected that the necessary ratifications will be made soon, and that the first meeting of the new International Whaling Commission can take place in late 1948 or early 1949.

Japanese Fishery Reports

The Fish and Wildlife Service, at the request of the Civil Affairs Division of the Department of the Army, has been processing and distributing reports on Japanese fisheries and fishery activities prepared by the Natural Resources Section of Headquarters of the Supreme Commander for the Allied Powers in Tokyo. Few reports on Japanese fishery activities and investigations prior to and during the war period were made available for foreign distribution and for translation into the English language. Condensations and summaries prepared by SCAP of Japanese fishery information of great interest to United States fishery and other business enterprises thus are made available by the Service.

Following is a list of publications prepared to date:

Fishery Leaflet No. 220. Glossary of Japanese fisheries terms.
Fishery Leaflet No. 229. Operation fisheries in Japan, by Reginald H. Fiedler.
Fishery Leaflet No. 230. The Japanese salmon industry.
Fishery Leaflet No. 234. Japanese fishing gear.
Fishery Leaflet No. 236. Fisheries education and research in Japan.
Fishery Leaflet No. 244. Conversion of selected Japanese weights and measures.
Fishery Leaflet No. 248. Japanese whaling in the Bonin Island area (A Preliminary Report).
Fishery Leaflet No. 261. A partial bibliography relating to agar, by Leonard S. Stoloff.
Fishery Leaflet No. 263. The Japanese agar-agar industry.
Fishery Leaflet No. 268. Japan's big fishing companies.
Fishery Leaflet No. 273. Survey of the fisheries of the former Japanese mandated islands, by Robert O. Smith.
Fishery Leaflet No. 279. Japanese fisheries production 1908–1946.
Fishery Leaflet No. 288. The (Japanese) fishing industry.
Fishery Leaflet No. 297. The Japanese tuna fisheries.
Fishery Leaflet No. 309. Japanese sponge culture experiments in the South Pacific islands, by A. R. Cahn.

The Fish and Wildlife Service also is engaged in the translation of certain publications which were closely guarded by the former Japanese Government, and which contain fishery information of great value in connection with the present and projected programs for the investigations, exploration, and development of fisheries of the Pacific Ocean.

Administration of Japanese Fisheries by the Supreme Commander for the Allied Powers in Tokyo

The policy pursued by SCAP, through the Fisheries Division of the Natural Resources Section, in administering the Japanese fisheries has been to confine Japanese operations within contiguous waters where, prior to the war, the Japanese fishing industry obtained more than 75 percent of the fish used for food by the Japanese people. There also has been an obligation to insure that Japanese operations in the fisheries conform strictly to the provisions of any international agreements to which the United States is a party. An exception to the area has been the Japanese

whaling operations in the Antarctic. Japan has operated two factory ships and a complement of killer boats during the 1946–47 and the 1947–48 seasons. The operations have been conducted under the surveillance of an inspector assigned by SCAP and inspectors assigned by various members of the United Nations. All of the whaling regulations promulgated pursuant to the International Whaling Agreements have been complied with strictly. This is in contrast to Japanese whaling operations prior to and during the war which resulted in a take of undersized whales as great as 40 percent as well as the indiscriminate killing of females accompanied by calves and total disregard of prescribed whaling seasons.

The report of the Fisheries Division of the Natural Resources Section, SCAP, for the period July 4–10 indicates that there are many flagrant violations by Japanese fishing industries of restrictions as to their area of operations. There are further indications that Japanese fisheries are so intensive that the catch per unit of effort is decreasing with a resultant pressure for an enlargement of the fishing area. It must be remembered that before the war the ever-increasing scope of Japanese fishing activities throughout the Pacific was prompted by the Japanese disregard for conservation and their utter ignorance of how to apply regulations for the purpose of maintaining a maximum sustained yield. It appears that despite the efforts of SCAP, the Japanese fishing industry is not applying conservation principles to its operations and that while there are many good fishery regulations which would conserve the resources in Japan, these are not being enforced. There are further indications that the Japanese fishing fleet has been overbuilt and is of a greater tonnage than prior to the war. When other nations fishing on the high seas have been forced to take measures for the conservation of their fisheries through the imposition of restrictions on the operations of industry, it would seem to be an obligation of SCAP to insure that the Japanese fishing industry is regulated so as to maintain and not deplete the resources.

The Fisheries Division of SCAP has made considerable progress during the year in reorganizing the Japanese fishery research program, in strengthening the work of the primary research stations and coordinating their efforts towards common objectives as well as discontinuing fruitless scattered research projects in minor institutions.

International (Halibut) Fisheries Commission

The International Fisheries Commission which was established in 1923 by treaty between Canada and the United States, was granted regulatory powers over the Pacific halibut fishery in 1930. Control of the fishery over the past 17 years has resulted in extensive rehabilitation of a severely depleted and over-exploited species. The abundance of marketable-sized halibut in 1947 was 144 percent higher on the grounds off British Columbia and southeastern Alaska and 89 percent higher on the grounds in the Gulf of Alaska and westward than in 1930 when the stocks in both the above areas had reached an all-time low.

Due to the effectiveness of the Commission's control measures and the response of the species to them, it has been possible from the outset not only to maintain but gradually to increase the annual yield taken from the grounds. In 1946 and 1947 the catch averaged 58,000,000 pounds a year or 14,000,000 pounds greater than the low level of yield in 1931 and 1932 when regulation began. This increase in landed catch, with its associated vitamin-bearing livers and viscera, represents an annual addition of over $3,500,000 to the income of the fishermen of the two countries. Significant from the economic standpoint is the fact that these larger annual yields are obtained with about one-third less fishing effort as a result of the improved condition of the stocks.

Regulations have consisted mainly of dividing the coast into areas according to the distribution of the relatively separate stocks, of setting catch limits for each important area, and of closing the areas as their catch limits are attained. This control of the total catch is supplemented by a statutory closed season at the time of spawning, the permanent closure of two nursery areas, the application of a minimum size limit, and the prohibition of destructive types of fishing gear.

The regulations have been based upon extensive biological, statistical, and oceanographical investigations. Due to the constant changes in the character of the fishery and in the stocks of halibut upon which it depends, a continuous program of observation is maintained to assess the effects of past regulations and to determine the course of future control.

The Commission's objective is to rebuild the stocks of halibut to their levels of maximum yield and to stabilize them there. As the program of rehabilitation in some areas now approaches the stage of maximum yield, the problems of management are becoming more complex. The dynamic relationships within the species at present levels of abundance are not adequately known. The increased abundance of halibut and the entry of vessels from other fisheries have greatly shortened the fishing season. This concentration of fishing and the interest in halibut displayed by vessels using other than the customary long-line gear have created problems affecting the proper utilization of the available stocks. Investigations are being directed to these problems. New types of regulatory measures involving broader authority may very well be necessary to cope with these conditions.

International Pacific Salmon Fisheries Commission

The immediate aims of the International Pacific Salmon Fisheries Commission may be summarized briefly as follows:

a. To give the fisherman as many fish as possible from those runs that are able to stand a fishery, while at the same time maintaining the necessary spawning stock or building it up—whichever is required.

b. To protect by fishery regulations those runs that are depleted so as to build up the spawning stock as rapidly as possible.

c. To provide free access for all runs to their spawning grounds and

improve conditions on those spawning grounds so as to obtain maximum production of young fish.

d. To rebuild runs in those areas in which the stocks have been reduced below the point where natural recovery would be possible within a reasonable length of time.

e. To insure the red salmon (sockeye) of proper recognition and protection in areas where power and irrigation developments occur.

f. To explore the possibility of opening up new areas to sockeye and of developing runs of commercial significance in them.

The staff of the Commission operates in two units—biological and engineering. The work is divided into projects which are, for the most part distinct in name only. Personnel in each unit overlaps from one project to another and the entire staff of each unit acts together in program planning. All work is aimed at the objectives outlined above and the two branches supplement one another. The fish ladders constructed by the engineering division at Hell's Gate, Bridge River, and Farwell Canyon resulted from biological investigations which proved the existence of blocks to upstream migration at those points and defined the water levels through which the blocks occurred. Upon completion of the ladders their efficiency was checked by biologists. The two branches are closely integrated elsewhere in stream surveys, in the spawning-ground surveys, and lately in the stream-improvement work. Such works as the Quesnel Field Station are located by the biological division who outline specifications. All problems of design and construction are then carried out by the engineers. The work of the two divisions is therefore closely integrated and supplementary in character.

Certain of the major projects of the Commission are outlined in the paragraphs that follow.

Extent of escapement and study of spawning grounds.—The purpose of this project is to determine the condition of each stock—the extent of the escapement, sex ratios, success of spawning, . . .; to determine the conditions upon the spawning grounds such as water height, temperatures, pollution, . . .; and to relate these conditions to the success of spawning.

Indian fishery.—This project involves primarily the collection of the statistics of catches made by Indians in various parts of the Fraser River watershed. Through tagging projects carried out at various points along the river and the recovery of these tags from the Indians it is possible to determine with fair accuracy the numbers of fish taken by the Indians from each run.

Study of the selective action of gill-net meshes.—The purpose is to determine the minimum mesh sizes needed for conservation purposes; the effects of varying sizes of mesh upon the sex ratios and the size of the fish escaping to the different areas; and the effects of the selective action of the nets upon the measures used to distinguish between individual populations.

Migration rates, rate of fishing, . . .—This project involves tagging at Sooke traps, Hell's Gate, and at various other parts of the river. Migration

rates of the different races have been rather well defined. The investigation will have to continue, however, in order to determine whether or not the changes in abundance of the different races will have any effect upon the migration rates or the time of migration. The problem of determining the rate of fishing has not yet been solved but it is the objective of an analysis now under way. If tagging can be utilized to measure this rate we shall have another reason for a continuation of this program.

Definition of races.—This project has been carried on for 10 years. Its purpose is to study the degree to which the stocks spawning in different areas may be separated by anatomical characters. A report is now in the process of preparation but the mass of data collected in past years will require considerable time to analyze.

Studies of young fish.—The purpose is to determine the conditions under which the young red salmon develop in each area; the nature of their early movements in the lakes and streams, the relationship between their abundance and rates of growth—in effect to determine the capacity of each rearing area in terms of young fish. Knowledge of the movements of the young fry and fingerlings from the time of hatching to the time they enter salt water will form a basis for determining a program of protection of red salmon in these areas where power and irrigation projects are planned.

Rehabilitation.—This project has been in progress for 2 years in the Quesnel area. Plans for a hatchery have been developed and construction will begin soon. The hatchery should begin operation in the fall of 1949. In a "pilot" experiment carried out during the past year with the assistance of the Washington State Department of Fisheries and the University of Washington, 42,000 young red salmon were planted in the Horsefly River. These fish were fed special diets and raised under temperature conditions that put them a year ahead in their growth. The purpose of this acceleration of growth was to attempt to bring them back as adult fish in 3 years. If this project is successful it may be possible to fill out "blank" years in areas where one good run now exists. Continuation of the experiment on a larger scale is planned for this fall.

Stream improvement.—This biological research involved here is new though some engineering work has been in progress for several years. Included are studies of "block" conditions that may develop in the river or on the spawning grounds, and of effects of stream clearance of log jams and other obstructions upon the spawning capacity of streams. The possible effects of power and irrigation development upon the lake and stream environment of the red salmon also will be studied. The project will have to be extended indefinitely and will be the principal foundation for protecting the runs of red salmon in the river.

Experiments on flow distribution in the pools of fishways.—This project has been conducted since 1945. The purpose of the experiment is to determine the capacity of the fishway pool for the passage of salmon. An approach from the engineering standpoint is necessary owing to a lack of basic information on the reactions of fish to various pool conditions. In

general, it is planned that these experiments will indicate the limitations in fishway designs for the passage of Pacific salmon through the pools.

Survey of spawning grounds—A land survey is being undertaken to delineate the major spawning areas of red salmon in the Fraser River system above the Fraser Canyon. The purpose of this survey is to index the usable areas and to leave permanent markers for the recording of annual changes, if any, in the spawning areas brought about by varying stream flows or ice conditions. In addition, this survey will encompass, as much as possible, the potential spawning areas now not available to sockeye because of natural or artificial obstructions.

Major construction projects.—Work has been completed on the two principal fishways and the high-level fishway on the right bank at Hell's Gate. There remain, in certain years, delay levels on the left bank at high flows and on the right bank at low flows. Salmon now pass through the Gate at levels above the operating fishways on the right bank and at levels below the operating fishways on the left bank. In order to offer equal passageways on both banks, improvements are to be installed in the form of auxiliary fishways to the principal structure as a high-level fishway on the left bank and a low-level fishway on the right bank.

The two fishways at Bridge River Rapids are complete except for paved access roads, and four fishways of the five planned have been built at Farwell Canyon. Owing to the delay of acquisition of necessary property rights, no work has been started, however, toward alleviating the conditions in Weaver Creek.

Only surveys have been made for many other stream-improvement measures in the form of fishways, screening of diversions, and the construction of fishways at natural or artificial obstructions. Other projects for the stabilization of channels in the delta areas will be undertaken upon the completion of both physical and hydrometric surveys.

COMMITTEE ON STATE AND NATIONAL RELATIONS

Wayne D. Heydecker [1]

In a federation like that existing in the United States, the relationships among the several states and the national government have been a fertile field for discussion since the adoption of the Constitution. Historical precedents, court decisions, Presidential proclamations, interstate compacts, Congressional acts, and state, regional, and federal administrative attitudes and personalities all have played a part in the evolution of the complex situation with which we are now dealing.

Background of Legal History

Rather than content ourselves with a superficial catalogue of incidents of federal-state cooperation or conflict it may prove worthwhile to review

[1] Secretary-Treasurer, Atlantic States Marine Fisheries Commission.

briefly the legal background. The decision of the U. S. Supreme Court in Shively *v.* Bowlby, 152 U. S. 1, contains an exhaustive review of the origins of state authority over wildlife and fisheries for each of the original English colonies along the Atlantic coast, and for the lands later obtained from Spain and France. In broad summary the powers of the colonies rested upon two long established doctrines of Roman Law, one of *imperium*: that the King as the head of the states had power to regulate the taking of *ferrae naturae* or wildlife and fish; the other of *dominium*: that the King as head of the states owned the wildlife and held it as trustee for all his subjects. These two doctrines have persisted side by side for centuries as complementary authorities. Some of our Atlantic seaboard colonies based their statute law more on one doctrine, some more on the other, but nearly all of them employed both doctrines at one time or another. When the colonies revolted against the English Crown they became free and independent nations and each became possessed of and asserted its complete sovereignty including the traditional controls over fish and wildlife.

When the new, sovereign little nations joined to form our federal union they delegated certain powers to the new national government through the federal constitution, reserving all others to the states. As each new state was admitted to the union it became possessed of powers equal to those possessed by the original thirteen states. In fact, Texas entered the union by an agreement which gave to her certain powers not possessed by other states.

Only twice since the formation of our federal union has the Congress enacted specific statutes for the regulation of the fisheries—once about 1889 for the regulation of the Atlantic mackerel fisheries and once in 1914 for the regulation of the sponge fisheries in the Gulf of Mexico. Both of these regulations were based on the broad authority of the commerce clause of the federal constitution and were upheld as valid by the Supreme Court. It thus appears that there is a valid authority for federal enactment governing the fisheries in territorial waters. However, a long line of other decisions of the Supreme Court, chief among which are McCready *v.* Virginia, 94 U. S. 391 (1877); Manchester *v.* Massachusetts, 139, U. S. 240 (1891); Geer *v.* Connecticut, 161, U. S. 519 (1896); the Abbey Dodge Case 223, U. S. 166 (1912); and Skiriotes *v.* Florida, 313, U. S. 69 (1941) had established the authority of the states to regulate marine fisheries within their territorial waters, to control the planting and harvesting of oysters within their jurisdiction, even, in the McCready case, to the point of limiting the privilege of doing so to citizens of the state, provided only that such state regulation did not contravene an act of Congress or violate the federal constitution.

In the regulation of inland wildlife the same general principles apply. The states have broad general powers to regulate the taking of wildlife and under the theory of ownership could restrict the taking to citizens or limit the export. The outstanding case of federal regulation in this field is in relation to migratory birds, but here it was not a question of mere federal

regulation superceding state laws. The migratory bird treaty with Canada did that, for a treaty with a foreign country duly ratified by the Senate becomes the supreme law of the land superseding any state laws in conflict with it. Consequently the treaty itself with its implementary legislation nullified and therefore required changes in many state laws relating to the taking of migratory birds.

Background of Interstate Cooperation

For many years it was the fashion among persons seeking governmental action to belittle the power and capacity of the states and to look to the federal government for action, but a quiet revolution has taken place in the last 15 years. In 1935 there came into being the Council of State Governments—a federation of the states for interstate cooperation. By 1945 it was functioning through duly established commissions on interstate cooperation in all 48 states. As a result of its leadership active assumption of responsibility by the states in many fields took the place of academic insistence on states' rights. Interstate commissions were established by compacts or other joint action for the clean-up and full development of the Delaware, Potomac, and Ohio River basins. New York, New Jersey, and Connecticut established the Interstate Sanitation Commission for their common waters. Nearly all of the states collaborated to make the Interstate Crime Commission a vital agency. Twenty-one states have established the Interstate Oil Compact. On the Atlantic coast 14 states have joined by compact with the consent of Congress to establish the Atlantic States Marine Fisheries Commission. The three Pacific states in 1946 similarly established the Pacific Marine Fisheries Commission. Three state legislatures among the Gulf states have adopted the Gulf States Marine Fisheries Compact which now lacks only formal congressional consent to become effective.[1]

Representatives of the three coastal groups have been organized into an Intercoastal Conference Committee which meets occasionally and corresponds between meetings. There has thus occurred during the last 15 years an amazing renaissance of state government and activity hitherto unparalleled in our governmental history.

The Presidential Proclamations—1945

After several years of exploratory study by the State Department, the President on September 28, 1945, issued two proclamations: (1) asserting the interest of the federal government in the protection and perpetuation of fishery resources "contiguous to its coasts" and the intent of the federal government to establish conservation zones for such purposes, unilaterally where nationals of the United States alone are involved, by treaty where nationals of other nations have already or may hereafter establish legitimate interests; (2) asserting the interest of the United States in and to the resources lying in or on the bed of the sea out to the limits of the continental shelf.

[1] Came into being with Congressional consent in 1949.

Both proclamations acknowledged the right of other nations to take similar action and since then Mexico and other Central and South American nations have done so. These two proclamations marked a departure from traditional national policy with respect to offshore fisheries, because for over a century and a half this country had stood pat upon the traditional doctrine of the 3-mile limit.

The Tidelands Case

In 1947 the Supreme Court handed down its famous decision in the so-called Tidelands Case, U. S. *v.* California, in which the court denied the claim that California owned the land under its territorial waters out to the 3-mile limit. The court did not support the claim of the federal government to ownership but asserted that the federal government had an overriding interest in and to the oil and other natural resources in the bed of the sea, but carefully distinguished and did not overrule the leading fishery cases previously cited, leaving apparently untouched the right of the states to adopt regulations governing marine fisheries so long as they did not conflict with a federal statute or the federal constitution.

While this case was pending in the Supreme Court, the Congress passed the McCarran-Sumner Resolution, S. J. res. 48, H. J. res. 225, 79th Congress, disclaiming for the United States any rights in lands beneath tidal waters within the 3-mile limit, only to have it vetoed by the President.

In the 80th Congress Senator Moore, for himself and 19 other Senators, including Senator McCarran who sponsored the former resolution, introduced a similar bill, S. 1988. The report of the Committee on the Judiciary with respect to this bill (Report No. 1592, Calendar No. 1649) is a most valuable and instructive document for all persons interested in these questions of relative federal and state jurisdiction. In the closing days of the session this bill was withdrawn from consideration at the request of several Senators but will undoubtedly be introduced in the session which convenes next January.

The immediate effect of the Tidelands decision was to cause a mild panic among state fishery administrators. The Committee on Offshore Jurisdiction of the Atlantic States Marine Fisheries Commission, composed of a number of attorneys- and deputy attorneys-general, however, digested the decision and concluded that the fishery cases were distinguished and not overruled and issued a bulletin to this effect to all members of the Intercoastal Conference Committee and to administrators of Atlantic coastal states.

Toomer *v.* Witsell and Takahashi *v.* California Fish and Game Commission

State administration of state fishery laws therefore continued but almost immediately was challenged in South Carolina, California, and Washington. The Takahashi case in California revolved around the Alien Exclusion Act of that state more than around the Tidelands decision, but the case of

Toomer *v.* Witsell in South Carolina raised the issue squarely as to whether the Tidelands decision divested South Carolina of her authority to regulate fisheries within her territorial waters. There was a general feeling of relief when the court recently handed down its decision. True, it declared unconstitutional as discriminatory a South Carolina statute establishing a $2500 license fee for out-of-state shrimp boats except those that had fished South Carolina waters for the three years immediately preceding. It also declared unconstitutional as an improper burden on interstate commerce a requirement of South Carolina that out-of-state boats land and package in a South Carolina port all shrimp caught in South Carolina waters.

The decision cleared away doubts raised by the Tidelands case by making it clear that the states retain the power to regulate fisheries within their territorial waters under the police power unless such regulation conflicts with a federal regulation, but it throws out the long-established proprietory doctrine of ownership at least with respect to migratory marine fish. It introduced the privileges and immunities clause of Article IV of the federal constitution as a check upon state laws affecting citizens of other states, and hinted that the "equal protection of the laws" clause of the XIVth Amendment may also be employed as a check.

The results of this newest decision may affect vitally the powers of the states and therefore the national-state relations which this Committee has been charged to report upon.

The Congress has consented to the Atlantic and Pacific coastal compacts, the former before, and the latter after the Tidelands decision. This action clearly indicates the intent of the Congress to consent to state regulation of the fisheries, for without that basic concept the compacts would be meaningless. If the next Congress consents to the Gulf Coast compact the position of the states will be further clarified and strengthened for that consent will be later than the decision in Toomer *v.* Witsell.

Federal-State Cooperation by Compact

The Atlantic States Marine Fisheries Compact adopted by the legislatures of 14 states and consented to by the Congress was the first instance of statutory cooperation at least in the fishery field, for it provided that the Fish and Wildlife Service of the U. S. Department of the Interior should be the primary research agency of the interstate commission. The Gulf Coast compact now awaiting Congressional consent follows this pattern but the Pacific Coast states did not wish the federal agency to be their research agency. Otherwise the compacts are almost identical.

For the Atlantic states I can report that the arrangement has been very satisfactory as our annual reports to the Congress and the states have testified. The federal officials have no vote and there are no federal members or federal funds appropriated to the Commission which is supported entirely by state appropriation, but the cordial, cooperative attitudes of both federal and state officials have been noteworthy.

Federal-State Cooperation through Administrative Agencies

Similar reports of cooperation between the U. S. Fish and Wildlife Service and the state administrative agencies dealing with the fisheries come from numerous states, both coastal and inland. Your committee member from Oklahoma, Mr. A. D. Aldrich, refers to these conditions in his general region as "healthy—improving rapidly and very congenial." He adds, "I wish we could be as optimistic about interstate relations," and refers to the difficulty of adjusting open and closed seasons, bag limits, and license fees on boundary lakes or other interstate waters. The states can reach agreements on such matters, we are sure, if they will call in the aid of the Council of State governments and the Commissions on Interstate Cooperation in the several states affected. These commissions have a way of solving difficulties when administrative agencies cannot, for two-thirds of the membership of such commissions is customarily drawn from the state legislature, which fact is of great help when it comes to coordinating the statutes of several states. Mr. Aldrich reports that there is especially fine cooperation between the Army Corps of Engineers and the Oklahoma Fish and Game Department, particularly with respect to 68 reservoir projects in the overall plan for water conservation which will create over half a million acres of water area in that state. Exchange of personnel between the two agencies has helped greatly to facilitate such cooperation. Similar conditions are reported for the surrounding states by Mr. Aldrich, who pointed out that the planning personnel of the Corps of Engineers are fully aware of the wildlife values in reservoir areas in the southwestern states. Field offices established by the Fish and Wildlife Service in connection with river-basin studies have likewise contributed to greater understanding and better federal-state relations. Mr. Aldrich points out however that there are still some gaps to be filled. There appears to him to be need for more cooperation between the Bureau of Reclamation and the state fish and game departments. A great many irrigation projects are being planned and the problems bid fair to be numerous unless better understandings are attained in advance.

Confirmation of Mr. Aldrich's comments as a state official, as well as a practical solution for the problem, comes from another committee member, Mr. John S. Gottschalk of the Fish and Wildlife Service. He reports for the area around Billings, Montana, the same kind of cordial relations that Mr. Aldrich describes for the southwest. Representatives of nine Missouri Basin states met with representatives of the Fish and Wildlife Service in April 1949 to draft a memorandum of understanding about the responsibility of the several state and federal agencies for various parts of the development program of the Missouri Basin.

The formation of this organization and the document now in preparation, Mr. Gottschalk believes, to be perhaps the most noteworthy example of federal-state cooperation in the central west. He adds, "The need for a basic policy has been recognized by many, and the memorandum of under-

standing will serve as a framework on which to support the cooperative management and development activities which are growing so rapidly in this region. With respect to fisheries, the formulation of policies governing the investigation and management of the 105 authorized reservoirs in the Missouri Basin is of prime importance."

Pollution of interstate waters continues to be a problem in some areas. Mr. Aldrich reports that some state officials, weary of trying to get action by interstate cooperation, look to federal control. The opposite attitude prevails along the eastern coast where the Interstate Commissions on the Delaware River basin, its counterpart on the Potomac River basin, and the Interstate Sanitation Commission operating jointly for New York, New Jersey, and Connecticut are making steady if not spectacular progress in clearing up their respective areas. In their work these interstate commissions have had excellent cooperation from federal officials in the Public Health Service and the Corps of Engineers.

Recently there came into being the Interstate Commission on the Ohio River basin created by compact embracing all the states on both sides of the Ohio River from its sources in New York and Pennsylvania to its junction with the Mississippi. The creation of this new commission is another milestone in federal-state relations. Like the Potomac River Commission it will have on it representatives of the federal government as well as the states. It should not be inferred from this comment, however, that the Interstate Sanitation Commission in the New York area or the Interstate Commission on the Delaware River basin have lacked the cooperation of federal agencies or failed to cooperate in return, for such cooperation has been outstanding.

Summary

Over recent years cooperation between state and federal agencies has increased in a noteworthy manner. Sometimes this cooperation has been effected by formal interstate compacts assented to by the Congress. Sometimes it has been by state statutes, but more often it has been through the voluntary cooperation of intelligent administrators in both federal and state services. These men are among the growing body of public servants who recognize that they serve a common employer, namely, the people of the several states who collectively constitute the nation, and that there is no place for petty jealousy in service to the people. They realize further that no good can come from the senseless complaints of some overzealous and usually uninformed persons who constantly belittle the capacity, the willingness, or the good faith of the states in the field of fisheries and of conservation generally. These men know also that without the existence and cooperation of the state conservation agencies, particularly in the field of fisheries, the task of the Fish and Wildlife Service would be an impossible one. Let us take comfort in the growing cooperation which it has been our pleasure to report. Let us have done with all pettiness. Our task is to help realize the great goal of fishery conservation—maximum sustained yield

consistent with preservation of the brood stock. Attainment of this goal will mean a plentiful supply of valuable foods for the consuming public, a decent living for the commercial fishermen, and assurances of good sport for the angler.

EDITORIAL BOARD

RALPH HILE

In the matter of progress in the improvement of publication schedules I would like to report four points: first, the issuance in late 1947 of Volume 74 of the TRANSACTIONS; second, the distribution to the members in the spring of last year of Special Publication No. 1, *A list of Common and Scientific Names of the Better Known Fishes of the United States and Canada;* third, repeated and convincing assurance from our printer that Volume 75 would be issued by the end of July 1948; fourth, distribution over the Labor Day weekend of the galley proof of most of the papers—19 of 24—of Volume 76.

Developments with respect to Volume 75 would appear to justify my attitude of last April when I suggested that the Society take steps immediately to obtain another printer or another editor, or both. One year, 2 weeks and 4 days have now elapsed since the Monumental Printing Company received complete copy for Volume 75. I have not seen that volume yet. The indicated rate of gain in our program to bring our printing back on schedule is not particularly impressive.

The progress on Volume 76 is far more encouraging. Despite the deep skepticism that past experience has engendered, I am inclined to believe—on the basis of facts, not promises—that this volume will be completed near the end of the present year. Indeed, it does not seem to be outside the range of possibility that Volume 76 might appear in advance of Volume 75, thereby creating a bibliographic curiosity unequalled since we omitted 38 in the numbering of our annual volumes.

The improvement in our printing service has been attained only at a price. Each copy of Volume 76 will cost the Society $4.20, plus the expense of distribution. As for Volume 77, the printer refuses to quote rates until current wage negotiations with the typographical union are completed.

REPORTS OF SPECIAL COMMITTEES

COMMITTEE ON REVISION OF THE CONSTITUTION AND BY-LAWS

H. J. Deason

It was expected that the Committee on Revision of the Constitution and By-laws would have completed its work and presented a final redraft of the constitution and by-laws for adoption at this meeting. However, when the Committee began to analyze the existing constitution and by-laws and recodify them it found many things on which it was difficult to make decisions. For example, although the constitution in some cases prescribed the duties of committees and officers, through custom of long standing (judging by the reports of committees and officers in recent years) some deviations have grown up by tradition. A great many problems of that type faced the Committee, and we believed that since we were revising the constitution and by-laws we should do a thorough job of it and let everyone who is interested have an opportunity to work with us. Accordingly the report of the Committee on the Revision of Constitution and By-laws is an interim report. We are presenting to you a preliminary draft of a revised constitution and by-laws which represents our best thinking for the moment.

The Committee wishes the members of the Society to have an opportunity to study the revised draft of the constitution and by-laws between now and next January 1, and send to us the copies which have been distributed, with your comments, suggestions, and criticisms. When those have been received—and I hope we shall receive many—the Commission will then prepare a revised draft which will be distributed to the members together with the call for the next annual meeting. It is hoped that the final vote can be taken on the revised constitution and by-laws at that meeting.

We have included in our revision of the constitution and by-laws certain points intended to meet current needs of the Society, on which we feel that the membership might wish to take action at this meeting. But to that end the Committee on Revision of the Constitution and By-laws will turn over to the Resolutions Committee drafts of three resolutions. The first resolution proposes the enlargement of the Editorial Board from five to eight members. This enlargement is recommended by the Editorial Board in view of the establishment of the Western Division, which will mean more editorial work, and in view of the plans looking toward the establishment of a new quarterly journal at some future date. The Editorial Board feels that its work will be facilitated by an increase of membership.

The second recommendation that will be turned over to the Resolutions Committee proposes the establishment of a Membership Committee as a permanent standing committee. Briefly the proposal as developed and dis-

cussed informally with many members of the Society is this: the Membership Committee shall consist of 12 members, under the chairmanship of the First Vice-President and with other members consisting of the Second Vice-President, the Secretary-Treasurer, and 9 additional members in good standing appointed by the incoming president within 30 days after his election. It is believed that the continuous efforts of a permanent membership committee will do much toward maintaining and increasing the membership of the Society.

The third recommendation will propose a general authorization for the creation of regional divisions and the immediate establishment of a Western Division.

COMMITTEE ON FORMATION OF WESTERN DIVISION

Fred A. Thompson

Pursuant to a resolution passed at the Denver meeting of the American Fisheries Society held September 10, 11, and 12, 1947, the incoming president was directed to appoint a committee of six to establish a western branch of the Society.

The committee appointed consisted of Fred A. Thompson, Chairman, Paul R. Needham, A. C. Taft, W. L. Reavley, J. L. Hart, and M. J. Madsen. By common agreement of the committee members, plans were made to meet with the Western Association of Game and Fish Commissioners through Mr. Ross Leonard, who was at that time President of the Western Association. Consent was received for the joint meeting which was held June 2, 3, and 4, 1948.

Early in the spring of this year a memorandum was sent to the chiefs of all state fishery divisions requesting that the recipient forward the memorandum to all employees and interested persons in that division. This memorandum explained the action of the parent body and the plans made by the special committee. It further encouraged all persons interested in fisheries, whether they were members or not, to attend the organizational meeting of the Western Division of the American Fisheries Society.

Along with this memorandum a tentative program was supplied. It may be well to note here that the program was not followed and the issue was confused by incorporating the agenda of the Western Division into the program of the Western Association as a fishery technical session. Corrections were made and the meeting was conducted as a convention of the American Fisheries Society.

In order that plans might be made for complete organization a nominating committee was appointed consisting of James C. Simpson, Chairman, Ray H. Hess, Paul R. Needham, M. J. Madsen, Cliff Millenbach, and D. S. Rawson. This committee made nominations for offices as directed in the Denver resolutions, that is for President, Vice-President, and Secre-

tary. The names submitted for the three offices were Paul R. Needham, John L. Hart, and Fred A. Thompson, respectively.

A resolutions committee also was appointed with A. C. Taft, Chairman and A. W. Yoder, R. C. Holloway, D. S. Rawson, Floyd Roberts, F. R. Hauck and Roy E. Barker as members. This committee presented five resolutions, all unanimously adopted as follows: (1) urging prompt passage of the Dingell Bill; (2) opposing the development of the Rouge River Project; (3) expressing appreciation to the local committee; (4) extending appreciation to Fred A. Thompson for his work as Provisional Chairman; and (5) offering appreciation to M. J. Madsen for his preparation of the program at the Western Division meeting.

On the afternoon of the first day papers were presented. F. R. Butler led a lively discussion of sports and fisheries in British Columbia. He was followed by Forrest R. Hauck, who presented the paper, "Preliminary observation on the harmful effect of the electric shocker to the rainbow trout (*Salmo gairdnerii*)." For the afternoon session of the second day the following papers were presented: "Survival of trout in streams," by Paul R. Needham; "Lake-management studies in Oregon," by R. C. Holloway; and "Estimating the fish productivity of Great Slave Lake of Canada," by D. S. Rawson. This, I believe, is a creditable showing of papers for our first session.

The afternoon of the third day was devoted entirely to a business session in which action was taken on the election of officers. The acceptance was unanimous of the nominations made by the Nominating Committee. The resolutions were passed as previously mentioned. It was unanimously agreed that the organization should be known as the Western Division of the American Fisheries Society. Also by unanimous vote, the officers, as elected, are to serve as the Time and Place Committee. The President was directed to appoint a committee to study and draft a constitution and by-laws under which the new organization should be operated, to be voted upon at the next meeting of the Western Division.

The President was empowered to appoint a Program Committee for the next meeting. The attendance at the business session was the largest of all meetings, with 43 registered names.

Mr. President, I wish to thank you for the privilege of serving as provisional Chairman on your Committee on Formation of the Western Division. I considered this work an important step forward in strengthening our Society in membership and, if our new Western Division is operated in accordance with the hope of all western members, we shall see not only a stronger Society in numbers but a much greater dispersion of valuable fishery information. But however vital this crucial step may seem to some, we must take every precaution that sovereignty of the parent society remains unimpaired, that there will be ever-increasing vitality and progress on the part of the American Fisheries Society.

COMMITTEE TO CONSIDER ESTABLISHMENT OF A QUARTERLY JOURNAL (SECOND REPORT)

REEVE M. BAILEY [1]

At the Seventy-seventh Annual Meeting of the AMERICAN FISHERIES SOCIETY this Committee recommended that the Society adopt plans for publishing a quarterly fishery journal and that the TRANSACTIONS, which should include symposia and panel discussions presented at the annual meetings, be continued as an annual business report of the Society. It was suggested further that no change in present publication policy be initiated until the Editorial Board had had sufficient time to bring the TRANSACTIONS up to date.

During the past year, Volume 74 has been published, and Volume 75 is expected to be mailed this month. The present backlog consists of Volumes 76 (which is in proof and should appear early next year) and 77. It is evident, therefore, that although the backlog has been reduced, publication of the TRANSACTIONS is still over a year behind schedule. It is hoped that within another year or two a return to our pre-war publication schedule can be effected.

Assuming realization of this hoped-for schedule of publication for the TRANSACTIONS, we may seriously consider launching a quarterly journal within two or three years. To embark upon such a venture, however, the Society must be able to carry an increased financial burden. The income available for publication is even now insufficient to meet printing costs. It may be estimated that continuance of an abbreviated TRANSACTIONS plus the establishment of a new quarterly journal would cost not less than $5,000 annually, and $6,000 might be considered a fair minimum to provide for contingencies, such as additional increases in publication costs. In view of the present low membership level and high costs of publication, the Committee does not feel that a new quarterly publication is feasible at this time.

Increase in the funds available for publication may be achieved either from higher dues, or through an enlarged membership. A moderate increase in dues seems inevitable, but a large increase would defeat its own purpose through the resulting loss in membership. Your Committee believes that the Society has been negligent in its efforts to increase the membership. We suggest that a standing Membership Committee be appointed to relieve the Secretary of one part of his over-heavy burden and to promote through all means possible the enlargement of the Society. A moderate increase in dues and success in a sustained membership drive should make possible the necessary increase in revenue which would permit continuation of the plans for establishment of a quarterly journal.

---

[1] In the absence of the Chairman, his report was presented by Ralph Hile, member of the Committee.

The committee makes the following recommendations:

1. That the Society consider a moderate increase in annual dues;
2. That a permanent Membership Committee be appointed;
3. That the plan to publish a quarterly journal be postponed until such time as the Society is financially able to undertake the change; and
4. That this Committee be dissolved until the Society is in financial condition to undertake the objectives for which it was appointed.

REPORTS OF SESSIONAL COMMITTEES

COMMITTEE ON TIME AND PLACE

O. Lloyd Meehean

The Committee on Time and Place considered two points concerning our meeting which is held jointly with the International Association of Game, Fish, and Conservation Commissioners.

First and probably most important was the question of the location of the meeting in 1949. The Committee voted that the meeting next year shall he held in Winnipeg, Manitoba, Canada, within the week beginning September 12. Other localities from which we received invitations were: Richmond, Virginia; Louisville, Kentucky; and Florida. A request was received from Boston to be considered in 1950 or 1951.

The second question considered by the committee was of a different nature. Recognizing how difficult it is for many people from the various states to go to the large number of meetings that have to be attended at the present time and in view of the fact that many of the organizations which are holding meetings of this kind have a common interest and that these organizations could be strengthened materially by meeting together, the Committee suggested that serious consideration be given to the coordination of meetings of the national conservation organizations, and that the presidents of the American Fisheries Society and the International Association of Game, Fish, and Conservation Commissioners be requested to appoint a joint committee, with representation from the Wildlife Management Institute, to explore the possibility of such a general meeting and report at a later date.

AUDITING COMMITTEE

Eugene W. Surber [1]

We have examined the books of the accounts of the Society and find them in good order. An impending deficit due to the increased printing and operating costs may be avoided by an increase in membership dues.

There follows an estimate of expenditure and income prepared by the Secretary-Treasurer:

Expenditures

Printing

Vol. 75 Monumental Printing Co., Baltimore, Md.	$3,000.00
Vol. 76 Craft Press, Ann Arbor, Mich.	4,200.00

[1] In the absence of the Chairman, his report was presented by R. P. Hunter, member of the Committee.

Vol. 77 Craft Press, Ann Arbor, Mich.	4,500.00
Call for 1949 meeting	50.00
Stationery	100.00
Salaries	
E. C. Young	$ 225.00
K. M. Kane	400.00
Travel	
K. M. Kane	200.00
Ralph Hile	100.00
Editing	
Ralph Hile	250.00
Stenographic	
R. P. Hunter	100.00
Western Division	50.00
Box rental	6.00
Bond	18.75
Shipping library to Ann Arbor	30.00
Shelves	100.00
Supplies	30.00
	$13,409.75

ESTIMATED FUNDS TO MEET EXPENDITURES

Cash balance, General Fund—Sept. 30, 1948	$ 1,714.39
Balance, Permanent Fund—Aug. 31, 1948	6,833.12
	$ 8,547.51
Anticipated Income from dues for 1948–1949	
Active 600—$6.00	3,600.00
States	980.00
Clubs and Dealers	210.00
	$ 4,790.00
	$13,337.51
Anticipated deficit	$ 72.24

RESOLUTIONS COMMITTEE

H. J. DEASON

1. Authorization for Establishment of Regional Divisions and of a Western Division

WHEREAS, The American Fisheries Society, at its Seventy-seventh Annual Meeting, held in Denver, Colorado, in September 1946, authorized the appointment of a Committee on Formation of a Western Division of the American Fisheries Society, and

WHEREAS, That Committee has reported to the Society at its Seventy-eighth Annual Meeting, held at Atlantic City, New Jersey, September 13-15, 1948, plans for the organization and establishment of such a regional division; now therefore

BE IT RESOLVED, That the Constitution is hereby amended in accordance with the following text:

1. Upon favorable action of the Society upon a petition presented to it at any regular meeting by not less than 25 members of the Society in good standing resident in a particular geographic region, there may be established a regional division of the Society.

2. Such regional division or divisions shall be organized in accordance with pertinent provisions of the Constitution and By-Laws.

3. Each such regional division may adopt and amend from time to time its own by-laws, which shall conform to the provisions of the Constitution and By-Laws of the Society. The by-laws of regional division upon adoption or amendment shall be reviewed by the Executive Committee of the Society to insure conformance with the Constitution and By-Laws of the Society, and no by-laws of regional divisions or amendments thereof shall be considered effective until such review by the Executive Committee of the Society and notification by the Secretary-Treasurer to the President of the regional division that such regional by-laws or amendments thereof are in conformity with the Constitution and By-Laws of the Society.

4. Each regional division shall elect its officers, which shall consist of a President, Vice-President, and Secretary. The President of any regional division shall be a member of the Executive Committee of the Society, and in his absence or inability to attend meetings of the Executive Committee the Vice-President of any regional division may act in his stead. The Secretary of any regional division of the Society shall serve as an assistant to the Secretary-Treasurer of the Society and shall carry out his duties in accordance with the procedures determined by the Secretary-Treasurer of the Society.

5. Any member of the Society who resides within a designated region in which a regional division of the Society may be established shall be considered a member of both such regional division and of the Society as a whole. Qualifications for membership in regional divisions shall conform to qualifications for membership in the Society. Members of the Society elected by regional divisions shall consist only of active and life members. The other classes of membership provided for in the Constitution shall be subject to election only by the Society.

6. The Executive Committee may allot to any regional division, from time to time, such sums from the treasury of the Society, as may be necessary to meet its expenses and to further through the regional division the purposes and objectives of the Society. Such allotted funds shall be disbursed by the Secretary of the regional division, in accordance with its by-laws and the decisions of its officers and membership.

7. The regional divisions may assess such special nominal fees in addition to the dues of regular members of the Society, as may be

necessary to meet any expenses of the regional divisions which are not properly chargeable to the regular funds of the Society.

8. At least one member of any standing committee appointed or elected in accordance with the By-Laws of the Society, shall be a member of each regional division established in accordance with the present Article, in so far as practicable.

and

BE IT FURTHER RESOLVED, That the By-Laws are hereby amended in accordance with the following text:

(a) In accordance with the provisions of the Constitution, there is hereby established a Western Division of the American Fisheries Society, which shall be constituted of members in good standing from the eleven western States and the territories of Alaska and Hawaii of the United States of America, and from the provinces of Saskatchewan, Alberta, and British Columbia of Canada.

(b) The President of the Western Division shall submit a report concerning its activities to the Society at each regular meeting.

(c) The Secretary of the Western Division shall submit an annual report to the Secretary-Treasurer of the Society which shall constitute a part of the annual report of the Secretary-Treasurer to the Society.

2. Membership Committee

WHEREAS, The American Fisheries Society is in need of continuous efforts and a well organized program for the purpose of maintaining and increasing its membership, and it is believed that such objectives can best be attained through the work of a well qualified standing committee; now therefore

BE IT RESOLVED, That the American Fisheries Society at its Seventy-eighth Annual Meeting at Atlantic City, New Jersey, September 13-15, 1948, authorizes the amendment of the By-Laws to provide for the establishment of a standing committee on membership in accordance with the following text:

The Membership Committee is a standing committee responsible for maintaining and increasing the membership of the Society. The committee shall take such measures as it deems appropriate and effective to stimulate interest in the Society and to further its purposes and objectives by interesting qualified persons in membership. The committee shall consist of 12 members, including the First Vice-President, the Second Vice-President, the Secretary-Treasurer, and nine other members in good standing who shall be appointed by the President within 30 days after his election. The First Vice-President shall serve as Chairman of the committee. The committee shall report annually to the Society.

3. Reorganization of Editorial Board

WHEREAS, The publication schedule of the Society can be facilitated by a reorganization of the Editorial Board of five members, and

WHEREAS, The establishment of a Western Division of the Society necessitates additional editorial service; now therefore

BE IT RESOLVED, By the American Fisheries Society at its Seventy-eighth Annual Meeting held at Atlantic City, New Jersey, September 13-15, 1948, that the By-Laws of the Society are amended by deleting present provisions relating to the Editorial Board, and inserting in lieu thereof the following:

> The Editorial Board is a standing committee of the Society responsible for the editing and publication of the proceedings of meetings, including technical papers, and other manuscripts of the Society. The committee shall consist of eight members in good standing and of proven ability, each of whom shall serve for a term of four years. Each president, immediately after his election, shall appoint two new members of the committee to succeed those whose terms have expired and shall designate the chairman for the ensuing year. The chairman of the committee shall be called the Editor and the other members shall be called Associate Editors. The Editor shall assign duties to the Associate Editors. When necessary to facilitate the work of the Board, the Editor may designate such additional members of the Society as may be necessary as Assistants to the Editor, who shall perform such duties under his immediate direction as he may determine.

4. Pollution Study Committee

WHEREAS, For the past several years the Society annually has authorized the appointment of a Pollution Study Committee appointed by the incoming President, and

WHEREAS, The interests of the Society will best be served by continuance of the committee for an additional year; now therefore

BE IT RESOLVED, That the incoming President, within 30 days of his installation shall appoint a Pollution Study Committee composed of not more than seven members in good standing, which committee shall concern itself with the problems of pollution in relation to fisheries, and shall report to the Society at its Seventy-ninth Annual Meeting.

5. Committee on Revision of the Constitution and By-Laws

WHEREAS, The continuance for one year of a Special Committee on Revision of the Constitution and By-Laws was authorized at the Seventy-seventh Annual Meeting, and the said committee has not found it possible to complete its duties, now therefore

BE IT RESOLVED, That the American Fisheries Society at its Seventy-

eighth Annual Meeting authorizes without change of membership the continuance of the Committee on Revision of the Constitution and By-Laws for an additional year, and the said committee shall submit a final report and recommendations at the Seventy-ninth Annual Meeting.

6. Change in the Rates of Dues

WHEREAS, The greatly increased cost of publishing the official papers of the Society in the Transactions, and the higher and ever-increasing cost of supplies, materials, postage, communications, and other essentials, threaten to cause an almost immediate deficit in the current fund of the Society, which deficit will ultimately lead to the total exhaustion of the financial reserves of the Society contained in the Permanent Fund unless provision for additional revenue is made; now therefore

BE IT RESOLVED, That the American Fisheries Society, at its Seventy-eighth Annual Meeting held at Atlantic City, New Jersey, September 13 to 15, 1948, amends its by-laws so as to increase dues and payments for the various classes of membership in accordance with the following schedule:

Active membership, from $3 to $4.50 per year.
Library membership, from $2 to $4 per year.
Life membership, from $50 to $75 payable in one sum, or in two consecutive annual payments of $37.50.
Patron, from a single donation of $50 or more, to a single donation of $250 or more.
State membership, from $30 to $40 per year,

and

BE IT FURTHER RESOLVED, That the present membership of clubs and dealers at $5 per year be hereby abolished, and that the By-Laws of the Society are hereby amended to provide for the establishment of a new category of member, to be known as a Sustaining Member at an annual rate of not less than $10 per year, such membership to be open to all persons, societies, corporations, firms, associations, organizations, or enterprises interested in the work of the Society and in the furtherance of its purposes and objectives; and

BE IT FURTHER RESOLVED, That the changes in membership dues and fees indicated above shall become effective on July 1, 1949.

7. Award of Honorary Membership to James A. Rodd

WHEREAS, James A. Rodd, member of the American Fisheries Society since 1919, President of the Society in the fiscal year 1931-32, former Director of Fish Culture of the Department of Fisheries of Canada, has been throughout his life an outstanding contributor to the development and advancement of fish culture and fishery management, and has been a

strong leader and continuous source of inspiration to all workers in fisheries, practical, technical and administrative, and

WHEREAS, Mr. Rodd throughout his 29 years as a member of the Society has been and is still an indefatigable worker for the advancement of the Society and of its purposes and objectives; now therefore

BE IT RESOLVED, That the American Fisheries Society, at its Seventy-eighth Annual Meeting held at Atlantic City, New Jersey, September 13–15, 1948, pays tribute to and recognizes the services and accomplishments of its distinguished member, James A. Rodd, by conferring on him an honorary membership in the Society and admitting him to all the rights and privileges appertaining thereunto.

8. Appreciation of Courtesies and Hospitality

WHEREAS, The Seventy-eighth Annual Meeting of the American Fisheries Society, held at Atlantic City, New Jersey, September 13–15, 1948, has been one of the most successful, interesting, and best attended within the memory of many present members of the Society, and

WHEREAS, The success of the meeting has resulted directly from the excellent facilities, educational and inspirational tours, the outstanding entertainment features, and the splendid press service provided and arranged by those in charge of plans for the meeting and for the administrative and hospitality functions connected therewith; now therefore

BE IT RESOLVED, That the American Fisheries Society extends its warmest expressions of appreciation and sincere thanks to Colonel Arthur F. Foran, Chairman of the Council, Division of Fish and Game, New Jersey Department of Conservation; to his most able assistants, Colonel Harrison Cook, Member of the Council, Division of Fish and Game; to Miss Anne E. Sullivan, Secretary of the Division of Fish and Game, and to the many others who have worked with them.

COMMITTEE ON NOMINATIONS

STILLMAN WRIGHT

Mr. President, your committee wishes to submit the following list of officers and committees for the ensuing year.

OFFICERS

President .....Seth Gordon, Pennsylvania
First Vice-President.....Milton C. James, District of Columbia
Second Vice-President .....A. S. Hazzard, Michigan
Secretary-Treasurer.....George E. Sprecher, Wisconsin
Librarian.....W. C. Beckman, Michigan

VICE-PRESIDENTS OF DIVISIONS

Fish Culture .....E. B. Speaker, Iowa
Aquatic Biology and Physics.....W. J. K. Harkness, Ontario
Commercial Fishing .....C. R. Carry, District of Columbia
Protection and Legislation.....Elliott S. Barker, New Mexico
Angling.....Willis King, North Carolina

COMMITTEE ON INTERNATIONAL RELATIONS

Albert M. Day, District of Columbia, *Chairman*
A. G. Huntsman, Ontario
M. J. Lindner, Mexico
J. A. Rodd, Ontario
Lloyd L. Smith, Minnesota
Fred A. Thompson, New Mexico
Marion Toole, Texas

COMMITTEE ON STATE AND NATIONAL RELATIONS

John Van Oosten, Michigan, *Chairman*
R. S. Campbell, Missouri
C. N. Feast, Colorado
C. R. Gutermuth, District of Columbia
O. L. Meehean, District of Columia

COMMITTEE ON COMMON AND SCIENTIFIC NAMES OF FISHES

Walter H.. Chute, Illinois, *Chairman*
Reeve M. Bailey, Michigan
W. A. Clemens, British Columbia
John R. Dymond, Ontario
Samuel F. Hildebrand, District of Columbia
George S. Myers, California
Leonard P. Schultz, District of Columbia

MR. WRIGHT: I move that the report be accepted, the nominations closed, and the Secretary instructed to cast one ballot for the persons named.

[Motion adopted unanimously.]

CONCLUDING BUSINESS

THE RETIRING PRESIDENT: Now I have a very important resolution to read:

BE IT RESOLVED, THAT the AMERICAN FISHERIES SOCIETY, at its Seventy-eighth Annual Meeting held at Atlantic City, New Jersey, September 13–15, 1948, acknowledges with sincere thanks and appreciation the services of its retiring Secretary-Treasurer, Russell P. Hunter, who has served the Society in such capacity and in a diligent manner for more than seven years; and in so resolving the Society especially recognizes his immeasureable contribution toward the maintenance and furtherance of the Society during the very difficult years of World War II.

I have much pleasure in moving the adoption of this resolution.

[The resolution was carried unanimously, by a rising vote, with applause.]

THE RETIRING PRESIDENT: I want to take this opportunity of thanking the entire membership, the officers, and the chairmen and members of the various committees, for the excellent cooperation I have received during the past year. I do not recall a single request on which I had a refusal. I appreciate deeply the honor of having served the Society for the past year, and I thank you most sincerely.

I will now ask Dr. Deason and Mr. Hayford to escort the president-elect to the chair.

[Mr. Gordon having been escorted to the rostrum.]

THE RETIRING PRESIDENT: Ladies and gentlemen, I present to you Seth Gordon. He needs no introduction to this Society or to any other connected with game, fish, or fisheries.

THE PRESIDENT-ELECT: Thank you, Dr. MacKay. Members of the Society, I deeply appreciate the honor you have conferred upon me. I do not believe anything I may have done for the Society merits such recognition, but I want to assure you that I shall do my best to help further the work of the Society during the coming year.

Having regard to the report read by the outgoing Secretary-Treasurer as to the financial status of the Society, it looks as if all the members will have to do a great deal of hard work during the coming year. We shall have to enroll many new members, and we must find ways of economizing until our new schedule of fees becomes operative. I hope you will not leave it to the President and a few others to beg, borrow or otherwise obtain the necessary funds to keep the Society going during the next twelve months. This is a task in which all of you can play an important part, and I am sure we can get over this hurdle if we all work at it. There are many who, I am sure, would be interested in membership, and these people should be solicited; I am laying that problem before you for consideration at this time.

If there is no further business, I declare the meeting adjourned.

[Whereupon the Seventy-eighth Annual Meeting of the American Fisheries Society was adjourned.]

Appendices

INSTRUCTIONS FOR PREPARING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(REVISED 1949)

Please check each item below before the final typing of your manuscript and help your Society reduce the costs of publication, save your Editorial Board (which works gratis) much needless work, time, and expense, and avoid delay in the publication of the *Transactions*.

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals (Government Printing Office Style Manual; University of Chicago Style Manual). Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. **Manuscript must be typewritten double-spaced,** including titles, headings, legends for tables and illustrations, and literature citations. Use one side only of sheet. Do not fold manuscript. Write manuscript only in simple upper and lower case. *Do not use all capital letters for any purpose and underscore only where italics are intended.*

2. **Carbon copies will not be accepted.** Do not use thin, transparent paper. Heavy bond paper is preferred.

3. **Margins** at top, bottom, and both sides must be no less than 1¼ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. **Pages** must be numbered in consecutive order, including the literature cited, tables, charts, and photographs. Tables and legends of charts and illustrations must be inserted near their place of reference in the text.

5. **Illustrations.** Make separate pages of tables with headings (not of leader work), of legends of diagrams, charts, and illustrations, and limit the number to those absolutely necessary to clarify or supplement text. *Tables and cuts cost money!* Only sharp, glossy photos can be used. All drawings, charts, and diagrams should be prepared in waterproof India ink on Bristol Board, other perfectly smooth white paper or cardboard, or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the shading lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed 4¼ by 6½ inches (inclusive of legends) when reduced. All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend. The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, maps, charts, and tables, and designate all of these, except tables, as figures, numbering them in consecutive order with Arabic, not Roman, numerals.

6. **Footnotes** in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the text by two

horizontal lines, one above and one below the note. In each new table footnotes should begin with 1.

7. **The title** of the manuscript, together with the author's name (write out in full either one or both of the Christian names and do not use "by"), position or department, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer.

REPORT ON THE DISEASES OF BROOK TROUT

John Edward Doe

Department of Conservation, Lansing, Michigan

8. **Underscore** (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius. Do not underscore any words unless italics are intended.*

9. Inspect papers in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. **Bibliographic references** in text should give name of author and year of publication in parentheses, thus (Doe, 1932). Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any reference not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below to be placed at end of paper:

Literature Cited

Doe, John C., J. W. Brown, and H. W. Green

1939. Report on the diseases of brook trout. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 450–461.

Note that the year of publication precedes the title and the year of the meeting is stated in the reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and very inaccurate. Help us correct this situation.

11. **Tables.** Every table should have a heading and must be typewritten on a separate page. Insert tables among the text pages near the points where they are

Item	Number of fish	Percentage of total	Average length millimeters	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	$0.25

discussed. In preparing tables please be certain that they are not too large to appear on a single printed page. Number tables consecutively with Arabic, not Roman, numerals (1, 2, 3, etc.). Abbreviate the word "number" (No.) when referring to a special number—not when referring to quantity or things. Spell all other words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date,* in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

12. **Capitals.** Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to a particular State, Government, and to organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Hoover Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but use lower case for a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of higher categories.

13. **Abbreviations.**

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.

Temperatures, F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

Number, if preceding figures—No. 125; otherwise spell out.

United States, if preceding name of a department or a bureau of a vessel, etc.—U. S. Department of the Interior, U. S. S. *Indiana.*

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5-Sept. 2 (but April-September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5-September 2.

Measures and weight, except p.p.m., 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage, 12 percent, a percentage of 25.5.

14. **Numerals.** Spell out all *isolated* numbers less than 10, but use figures in a group of enumerations when any one number of that group is 10 or greater. Do not spell out numbers of two or more digits (except round numbers of approximations: estimated at five hundred; a thousand fish), and always use a comma in a number of four or more digits. Treat alike all numbers in a series of connected groups. For example: There were nine trout. There were 9 trout, 120 bass, and 50 pike.

Use figures for all enumerations of quantities and measurements, such as dimension, weight, area, volume, distance, clock time, time, money, percentage, degrees, proportion or ratios, ages, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone: one-eighth inch). For example: $3.00 per 20 pounds; 5 feet 6 inches; 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes; 25.5 percent; 75° F.; 1:10,000; trout 2 years 6 months old;

2-year-old trout; June 29, 1936; the 1st of January, 1938; the 20th day of March; 1937-38; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enumeration exceeds 100: ten 12-room houses; twenty 6-inch trout; 120 6-inch trout.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout," but write "Two hundred fifty bass and 325 trout were shipped."

Spell out such indefinite expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout.

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. **Use of hyphen.** Many compound words when used as nouns are not hyphenated but require the hyphen when used as adjectives. For example note the following sentence: "This species is adapted to *"cold water."* "Trout are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

Write "largemouth" and "smallmouth" as one word when referring to black bass.

III SUBJECT MATTER

16. **Condense your paper** to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. **Papers which are too poorly written will be rejected.**

17. **Be definite in references to species.** The scientific name, and wherever needed the *complete* common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as "Bass," "trout," and "pickerel" apply to any one of several species. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth black bass," "brook trout," "rainbow trout," etc.

18. **Things to avoid.** Words that do not appear in the dictionary in the sense employed should be avoided. The words "case," "instance," "show," "found," "gave," and "present" are greatly overworked in manuscripts.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives*. Please check your manuscript for this exceedingly common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: *"This* was true in every *case." "The mortality* was *high* in every *pond."*

Avoid the use of a long series of nouns and adjectives as modifiers.

Avoid the use of such meaningless section headings as "Data" and "Discussion."

19. **Abstract of paper.** Give a brief abstract at the beginning of your paper. Do not include a "Summary" at the end of your paper; if "Conclusions" are given make them brief and not a duplication of materials in the abstract.

Prepared by the Editorial Board
February 1937 (revised 1949)

AMERICAN FISHERIES SOCIETY

List of Members

HONORARY MEMBERS

The President of the United States.
The President of Mexico.
The Secretary of the Interior of the United States.
The Governors of the several States.
The Governor-General of Canada.
The Lieutenant-Governors of the several Canadian Provinces.
The Dominion Minister in Charge of Game and Fisheries.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'40 Gordon, Seth, Dept. of Fish & Game, Ferry Bldg., San Francisco, Calif.
'19 Rodd, J. A., Dept. of Fisheries, Ottawa, Ont.

PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15 Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour and Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Co., San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie and Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Washington
'15 California Barrel Co., 22nd and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore and Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Co., San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.
'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co., C. W. Weld, Mgr., 301 Brannon St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., and Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3d St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Bldg., Baltimore, Md.
'15 Linen Thread Co., The, W. A. Barbour, Mgr., 443 Mission St., San Francisco, Calif.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Pacific Hardware and Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Pope and Talbott, Foot of 3d St., San Francisco, Calif.
'15 Puget Sound Navigation Co., Seattle, Wash.
'15 Schmidt Lithograph Co., 2nd and Bryant Sts., San Francisco, Calif.

'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Ave., Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co., of California, Standard Oil Bldg., San Francisco, Calif.
'15 U. S. Rubber Co. of California, James B. Brady, Gen. Mgr., 2nd and Folsom Sts., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

LIFE MEMBERS

Compiled August 10, 1949

'12 Barnes, Earnest, Mass. Conservation Dept., 15 Ashburton Place, Boston 8, Mass.
'49 Bauer, Wm. B. A., 113½ E. Miner Ave., Ladysmith, Wis.
'48 Beakbane, Lionel R., Gansevoort, N. Y.
'38 Beckman, Wm. C., Colorado Coop. Wildlife Research Unit, Colorado A. and M. College, Fort Collins, Colo.
'00 Beeman, Henry W., New Preston, Conn.
'13 Belding, David L., 80 East Concord St., Boston, Mass.
'50 Benson, Arthur, % W. W. Mildrum Jewel Co., East Berlin, Conn.
'97 Birge, E. A., 2011 Van Hise Ave., Madison 5, Wis.
'35 Brown, Louis P., Insurance Building, Glens Falls, N. Y.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'50 Byram, S. H., % Grassyfork Fisheries, Inc., Martinsville, Ind.
'26 Cary, Guy, 55 Wall St., New York, N. Y.
'04 Coker, Robert E., University of North Carolina, Chapel Hill, N. C.
'47 Cornell, James H., Biology Dept., V.P.I., Blacksburg, Va.
'01 Dean, Herbert D., Northville, Mich.
'15 Folger, J. A., Howard & Spencer Sts., San Francisco, Calif.
'46 Fukano, Kiyoshi G., University Museums Annex, Ann Arbor, Mich.
'22 Grammes, Charles W., Hamilton Park, Allentown, Pa.
'03 Gray, George M., Marine Biological Lab., Box 89, Woods Hole, Mass.
'28 Hall, W. A., Co., Gardiner, Mont.
'10 Hopper, George L., Havre de Grace, Md.
'36 Hunter, R. P., State Board of Fisheries and Game, Hartford, Conn.
'23 Kienbusch, C. O., 12 East 74th St., New York 21, N. Y.
'33 Kingsbury, Oliver R., 83 Crescent Drive, Albany 3, N. Y.
'22 Kulle, Karl C., Suffield, Conn.
'26 Lackland, Sam H., 69 S. Ann St., Mobile, Ala.
'37 Lagler, Karl F., Natural Science Bldg., Ann Arbor, Mich.
'26 Low, Ethelbert I., 256 Broadway, New York, N. Y.
'43 McConica, T. H., III, 612 E. Ellsworth St., Midland, Mich.
'15 Mailliard, Joseph, 1815 Vallejo St., San Francisco, Calif.
'16 Nelson, Charles A. A., Lutsen, Minn.
'07 Newman, Edwin A., 4205 8th St., N.W., Washington, D. C.
'32 Nicholas, E. Mithoff, 20 S. Third St., Columbus, Ohio
'10 Osburn, Raymond C., Ohio State University, Columbus, Ohio
'04 Palmer, Theodore S., 1939 Biltmore St. N. W., Washington 9, D. C.
'10 Radcliffe, Lewis, 5600 32nd St. N. W., Washington 15, D. C.

'46 Sundara Raj, B., 6 A. P. Sen Road, Lucknow, W. P., India
'34 Roach, Lee S., Division of Conservation and Natural Resources, Columbus 15, Ohio
'43 St. Bernard Fish and Game Club, St. Alexis des Monts, P. Q.
'13 Timson, William, Alaska Packers' Association, San Francisco, Calif.
'11 Valette, Luciano H., Buenos Aires, Argentina, South America
'22 Walcott, Frederic C., Norfolk, Conn.
'97 Wood, Colburn C., Box 355, Plymouth, Mass.
'30 Wright, Stillman, U. S. Fish and Wildlife Service, Washington 25, D. C.

ACTIVE MEMBERS

'47 Abagon, Mariano A., Philippine School of Fisheries, Navotas, Rizal, P. I.
'48 Adams, Arthur K., University Museums Annex, Ann Arbor, Mich.
'47 Adams, Fred, Western Wyoming Hatchery, Auburn, Wyo.
'30 Ainsworth, A. L., Tuxedo Fisheries, Tuxedo Park, N. Y.
'47 Ainsworth, B. D., Ashton, Idaho
'34 Albert, W. E., Jr., Lansing, Iowa
'44 Alcorn, Joseph R., R.F.D. 1, Box 19A, Fallon, Nev.
'32 Aldrich, A. D., Box 75, Spavinaw, Okla.
'35 Alexander, George J., Parliament Bldg., Victoria, B. C.
'49 Allen, Donald J., 2121 Lake Avenue, Wilmette, Ill.
'37 Allen, Edward W., Northern Life Tower, Seattle, Wash.
'50 Allen, J. Frances, Dept. of Zoology, Univ. of Maryland, College Park, Maryland
'48 Allen, K. Radway, Box 202, Wellington, New Zealand
'29 Allen, William Ray, Dept. of Zoology, University of Kentucky, Lexington, Ky.
'49 Allin, Roger W., Route 2, Carterville, Ill.
'43 Allison, Leonard N., State Fish Hatchery, Grayling, Mich.
'49 Allsopp, W. Herbert L., Fisheries Survey, Dept. of Agriculture, Georgetown, British Guiana, South America.
'49 Allum, Marvin O., Dept. of Zoology, University of Michigan, Ann Arbor, Mich.
'45 Alvarez del Villar, Jose, Vasco de Quiroga 15, Santa Fe, D. F. Mexico
'49 Andersen, Edward H., 915 Sunnyside Drive, Ann Arbor, Mich.
'45 Anderson, Andrew W., U. S. Fish and Wildlife Service, Washington 25, D. C.
'08 Anderson, August J., Box 704, Marquette, Mich.
'41 Anderson, Bertil G., West Virginia University, Morgantown, W. Va.
'47 Anderson, G. M., Box 47, Glenwood, N. M.
'49 Anderson, Ima F., Yazoo City, Miss.
'43 Anderson, William W., City Pier, Sarasota, Fla.
'49 Andrews, Jay D., Virginia Fisheries Laboratory, Yorktown, Va.
'49 Andrews, R. M., 1530 Sherman St., Denver, Colo.
'49 Andrews, Thomas J., Dept. Zoology-Physiology, Fernnald Hall, University of Massachusetts, Amherst, Mass.
'24 Annin, Harry K., Spring St., Caledonia, N. Y.
'14 Annin, Howard, Chilmark Park, Ossining, N. Y.
'49 Anthony, E. H., Wolfville, N. S.
'47 Anthony, James D., 2655 Bellewood Ave., East Ann Arbor, Mich.
'46 Applegate, Vernon C., University Museums Annex, Ann Arbor, Mich.
'49 Appelget, John G., Cohasset, Minn.
'49 Armstrong, G. C., % District Forester's Office, Port Arthur, Ont.
'49 Asselin, Louis G., Box 440, St. Vincent de Paul, Co. Laval, P. Q.
'30 Atkinson, C. J., Fisheries Department, Ottawa, Ont.
'49 Atz, James Wade, 697 Tremont Court, Orange, N. J.
'48 Ault, Bud, Box 926, Chelan, Wash.
'33 Baer, Harry D., Box 200, Coleman Station, Anderson, Calif.
'47 Bagley, Lester, 311 W. 4th Ave., Cheyenne, Wyo.

'48 Bailey, Jack E., 820 S. 10th St., Bozeman, Mont.
'49 Bailey, Jos. R., Duke University, Durham, N. C.
'37 Bailey, Reeve M., Univ. of Michigan, Ann Arbor, Mich.
'33 Bailliere, Lawrence, Ozark Fisheries, Stoutland, Mo.
'37 Baker, Clinton L., % Southwestern, Memphis, Tenn.
'47 Balen, Aurum C., U. S. Fisheries Sta., Neosho, Mo.
'13 Balch, Howard K., 100 E. Seeboth St., Milwaukee, Wis.
'49 Baldwin, Norman S., 67 Burnaby Blvd., Toronto, Ont.
'38 Ball, Robert C., Michigan State College, East Lansing, Mich.
'49 Balmer, Robert R., 203 Monroe Ave., Wilmington Manor, New Castle, Del.
'23 Bangham, Ralph V., Wooster College, Wooster, Ohio
'49 Banner, Roy A., Washington State Dept. of Game, Seattle, Wash.
'49 Barber, Robert C., University Museums Annex, Ann Arbor, Mich.
'39 Barker, Elliott S., State Game and Fish Commission, Santa Fe, N. M.
'49 Barker, R. E., Questa, N. M.
'45 Barnaby, Joseph J., 2725 Montlake Blvd., Seattle 2, Wash.
'45 Barnickol, Paul G., Conservation Commission, Monroe Bldg., Jefferson City, Mo.
'46 Barr, Harry G., 424 Garrison Ave., Fort Smith, Ark.
'49 Barreda, Mario, Av. Primavera, Miraflores, Lima, Peru
'49 Barrett, Paul H., Dept. Biological Science, Michigan State College, East Lansing, Mich.
'47 Bartsch, Alfred F., Div. of Stream Pollution, Swan Island, Bldg. 24, Portland 18, Oregon
'48 Bates, Joseph D., Jr., 114 Hopkins Pl., Longmeadow, Mass.
'50 Bates, Stewart, Dept. of Fisheries, Ottawa, Ont.
'49 Baxter, George T., Lab. of Vertebrate Biology, University of Michigan, Ann Arbor, Mich.
'49 Beatty, Robert O., Izaak Walton League of America, 31 N. State St., Chicago 2, Ill.
'49 Beckman, Ray L., 1524 23rd Ave., Monroe, Wis.
'47 Beckman, William R., Fish and Game Dept., Oregon State College, Corvallis, Wash.
'47 Bell, Thomas A., Wyoming Game and Fish Dept., Cheyenne, Wyo.
'38 Bennett, George W., Illinois Natural History Survey, Urbana, Ill.
'47 Bennett, Leslie H., U. S. Fisheries Station, New London, Minn.
'49 Benson, Norman G., Wilcox Ave., East Berlin, Conn.
'49 Bentz, Ted, Lock Box 799, Marquette, Mich.
'47 Berquist, Howard, State Fish Hatchery, St. Croix Falls, Wis.
'38 Berube, Louis, School of Fisheries, Ste. Anne de la Pocatière, P. Q.
'49 Bevan, Donald E., 1107 Cherry St., Seattle, Wash.
'47 Biddle, Nicholas, 1600 Arch St., Philadelphia 3, Pa.
'35 Bishop, Sherman C., University of Rochester, Rochester, N. Y.
'42 Blair, A. A., Fisheries Research Laboratory, St. John's, Newfoundland
'49 Bleecker, Ronald L., 408 S. 4th Ave., Ann Arbor, Mich.
'47 Blosz, John, U. S. Fish and Wildlife Service, 316 Glenn Bldg., Atlanta, Ga.
'40 Bode, I. T., Conservation Commission, Jefferson City, Mo.
'44 Bond, Horace P., 121 Grant St., Bangor, Me.
'39 Bonham, Kelshaw, University of Washington, Seattle 5, Wash.
'48 Bonn, E. W., 1505 W. Johnson, Denison, Texas
'49 Bordawekar, B. R., School of Fisheries, University of Washington, Seattle 5, Wash.
'48 Borell, A. E., Box 1348, Albuquerque, N. M.
'48 Borges, Milton H., 4727 N. 6th St., Phoenix, Ariz.
'47 Borovicka, Robert L., 715 N. E. 20th St., Apt. 5, Portland, Ore.
'00 Bower, Ward T., 6011 Nevada Ave., Washington 15, D. C.
'47 Bradford, Arthur D., State Fish Hatchery, Bellefonte, Pa.
'49 Brasch, John G., N. W. Fishery Area Headquarters, Spooner, Wis.
'49 Brashear, Robert L., Parkview, N. M.

'20 Breder, C. M., Jr., American Museum of Natural History, New York, N. Y.
'47 Brickey, Monte R., Burney Creek Hatchery, Burney, Calif.
'44 Briggs, John C., 1146 Hamilton Ave., Palo Alto, Calif.
'49 Bromley, Albert W., N. Y. State Conservation Dept., Arcade Bldg., Albany 7, N. Y.
'49 Brower, Alfred D., Box 187, Newaygo, Mich.
'35 Brown, C. J. D., Montana State College, Bozeman, Mont.
'31 Brown, James, Dept. of Wildlife and Fisheries, Civil Courts Bldg., New Orleans 16, La.
'44 Bryan, Paul, R. F. D. 1, Dacatur, Ala.
'50 Buck, D. Homer, Cordell Hall, Stillwater, Okla.
'49 Budd, John C., Box 196A, R. 2, Mukwonago, Wis.
'20 Buller, C. R., State Fish Hatchery, Bellefonte, Pa.
'49 Burdick, George E., 383 E. Main St., Rochester 4, N. Y.
'49 Burner, Clifford J., U. S. Fish and Wildlife Service, 2725 Montlake Blvd., Seattle, Wash.
'48 Burress, Ralph M., Wildlife Conservation Bldg., University of Missouri, Columbia, Mo.
'49 Burrows, Charles R., Div. of Game and Fish, 355 Shubert Bldg., St. Paul 2, Minn.
'40 Burrows, Roger E., U. S. Fish and Wildlife Service, Leavenworth, Wash.
'36 Butler, Frank R., 567 Burrard St., Vancouver, B. C.
'31 Butler, George Edw., 311 Kingston Crescent, St. Vital, Man.
'47 Butler, Laurence M., Star Prairie, Wis.
'48 Butler, Robert L., 1046 23rd Ave., S.E., Minneapolis 14, Minn.
'49 Butrim, Edward J., Cornell Fish Hatchery, Cornell University, Ithaca, N. Y.
'49 Byrn, John W., P. O. Box 1381, Billings, Mont.
'27 Cable, Louella E., 1220 E. Washington Street, Ann Arbor, Mich.
'46 Caine, Lou S., James Heddon's Sons, Dowagiac, Mich.
'50 Calderwood, Margaret M., Scripps Institute of Oceonagraphy, La Jolla, Calif.
'40 Calhoun, Alexander J., Division of Fish and Game, Ferry Bldg., San Francisco, Calif.
'41 Campbell, Charles J., 933 S.W. Cheltenham St., Portland, Ore.
'49 Campbell, DeWayne E., 1679 Darien Court, Willow Run Village, Mich.
'45 Campbell, Robert S., 109 Wildlife Conservation Bldg., University of Missouri, Columbia, Mo.
'47 Canfield, Harry L., U. S. Fisheries Station, LaCrosse, Wis.
'48 Capel, Robert, 207 Muskrat St., Banff, Alberta
'47 Caraway, Prentice A., Box 52, East Lansing, Mich.
'36 Carbine, William F., U. S. Fish and Wildlife Service, Dept. of Interior, Washington 25, D. C.
'43 Carlander, Kenneth D., Iowa State College, Ames, Iowa
'48 Carry, Charles R., 1739 H St., N.W., Washington, D.C.
'49 Carufel, Louis H., Jr., 432 "O" St., Antioch, Calif.
'46 Chance, Charles J., Box 443, Norris, Tenn.
'49 Chapman, W. M., 3631 Everett St., N.W., Washington, D. C.
'50 Chidambaram, K., West Hill, P. O. S. Nalabar, India
'45 Chilton, Cyrus H., U. S. Fish and Wildlife Service, 18 S. King St., Hampton, Va.
'44 Churchill, Warren S., State Fish Hatchery, Woodruff, Wis.
'30 Chute, Walter H., John G. Shedd Aquarium, Grant Park, Chicago, Ill.
'47 Claridge, John H., 814 French Street, Three Rivers, Mich.
'47 Clark, Clarence F., State Fish Farm, No. 1, St. Mary's Ohio
'41 Clark, Ernest D., 826 Skinner Bldg., Seattle 1, Wash.
'37 Clark, O. H., Jr., R.F.D. 4, Ann Arbor, Mich.
'47 Clarke, Minor E., Division of Game and Fish, Frankfort, Ky.
'49 Cleary, Robert E., 912 First Ave., Vinton, Iowa
'21 Clemens, Wilbert A., Dept. of Zoology, Univ. of British Columbia, Vancouver, B. C.

'49 Clineschmidt, Henry, Temple Hotel, Redding, Conn.
'35 Cobb, Kenneth E., Windsor Locks, Conn.
'47 Coker, Coit M., Dept. of Research and Education, Solomons, Md.
'17 Cook, Ward A., U. S. Fish and Wildlife Service, Duluth, Minn.
'41 Cooper, Edwin L., Pigeon River Trout Research Area, Vanderbilt, Mich.
'34 Cooper, Gerald P., University Museum Annex, Ann Arbor, Mich.
'35 Cooper, R. B., 914 Grand Ave., Des Moines. Iowa
'47 Cope, Oliver B., North Rotunda, Museum Bldg., Stanford University, Palo Alto, Calif.
'47 Copeland, T. H., 4249 Linden Hills Blvd., Minneapolis, Minn.
'49 Copper, Fay A., U.S. Fisheries Station, Route 3, Muscatine, Iowa
'34 Corcoran, John P., Box 4066 Univ. Sta., Tucson, Ariz.
'46 Cosgrove, P. E., 87 Kameruka Rd., Northbridge, Sydney, N.S.W. Australia
'47 Cottam, Clarence, U. S. Fish and Wildlife Service, Washington 25, D. C.
'38 Cox, Harry B., U. S. Fish and Wildlife Service, Carson, Wash.
'48 Cox, John J., 43 Observation Hill, Columbia, Mo.
'47 Cox, William D., 24 N. Wacker Dr., Chicago 6, Ill.
'47 Cozort, Clarence E., Valley City, N. D.
'41 Cramer, Frederick K., P. O. Box 392, Red Bluff, Calif.
'13 Crandall, A. J., Ashaway Line and Twine Mfg. Co., Ashaway, R. I.
'34 Croker, Richard, California Fish and Game Div., Ferry Bldg., San Francisco, Calif.
'28 Crosby, Col. W. W., 1040 Adella Ave., Coronado, Calif.
'47 Cross, Frank B., 1515 West 9th St., Stillwater, Okla.
'49 Crowe, Walter R., University Museums Annex, Ann Arbor, Mich.
'45 Cuerrier, Jean-Paul, Dept. of Mines and Resources, Dominion Wildlife Service, Ottawa, P. Q.
'08 Culler, Capt. C. F., 3441 Fremont Ave. So., Minneapolis, Minn.
'37 Curran, H. Wesley, Dept. of Biology, Queen's University, Kingston, Ont.
'23 Curtis, Brian C., Faradawn, St. Helena, Calif.
'47 Daiber, Franklin C., Dept. of Biology, Alfred University, Alfred, N. Y.
'49 Dalley, Jess, Logan, Utah
'49 da Silva, Ayrton Goncalves, Av. Bartolomev de Gusmao 192, Santos—Estado de S. Paulo, Brazil
'47 Davey, Simon H., Box 7, Plainville, Conn.
'49 Davies, Isla V., 1035 22nd St., South, Arlington, Va.
'35 Davis, George Wm., Fish and Game Service, Montpelier, Vt.
'23 Davis, H. S., Clairborne, Md.
'47 Davis, Hosea L., Corning Arkansas Fisheries Sta., Corning, Ark.
'47 Davis, William B., Jr., 12141 Plainview Ave., Detroit 28, Mich.
'40 Day, Albert M., U. S. Fish and Wildlife Service, Washington 25, D. C.
'34 Deason, H. J., U. S. Fish and Wildlife Service, Washington 25, D. C.
'49 DeBusk, Kelly, Game and Fish Dept., Oklahoma City, Okla.
'26 DeCozen, Alfred, 970 Broad St., Newark 2, N. J.
'41 DeGruchy, James, Natural Resources Sec., A.P.O. 500 % Postmaster, San Francisco, Calif.
'41 DeLacy, Allan C., University of Washington, Seattle 5, Wash.
'38 Delisle, Henry A., U. S. Fish and Wildlife Service, Berlin, N. H.
'47 Demann, Joseph G., 3144 Passyunk Ave., Philadelphia 45, Pa.
'24 Dence, Wilford A., N. Y. State College of Forestry, Syracuse 10, N. Y.
'44 Dendy, Jack S., Dept., Zoology-Entomology A.P.I., Auburn, Ala.
'19 Denmead, Talbott, 2830 St. Paul St., Baltimore, Md.
'47 du Plessis, S. S., Inland Fisheries Dept., Stellenbosch, South America
'45 Dequine, John F., Game and Fresh Water Fish Commission, Tallahassee, Fla.
'48 DeVilbiss, Robart A., 11 Crescent Ave., Summit, N. J.
'49 Dickson, Arthur W., Biology Dept., Virginia Polytechnic Institute, Blacksburg, Va.
'39 Dill, William A., 1842 McKinley Ave., Fresno 4, Calif.

'43 Dimick, Roland E., Oregon State College, Corvallis, Ore.
'43 Doan, Kenneth H., 903 McArthur Bldg., Winnipeg, Man.
'47 Dole, Sanford B., Jr., Box 392, Red Bluff, Calif.
'33 Domogalla, Bernhard, 723 Johnson St., Madison 5, Wis.
'35 Donaldson, Lauren R., University of Washington, Seattle, Wash.
'47 Donley, Benjamin F., U. S. Fish and Wildlife Service, Boston 11, Mass.
'36 Doudoroff, Peter, U. S. Public Health, East 3rd and Kilgour Sts., Cincinnati 2, O.
'47 Douglas, Philip A., Emporium Bldg., 13 E. Philadelphia St., Whittier, Calif.
'37 Douglass, Edward J., U. S. Fish and Wildlife Service, Washington 25, D. C.
'45 Drake, Robert A., 450 Marsh Ave., Reno, Nev.
'47 Duck, Lester G., 1531 S. Yorktown St., Tulsa, Okla.
'28 Dunlop, Henry A., University of Washington, Seattle 5, Wash.
'49 Dye, Lyle, Wisconsin Conservation Dept., Madison 2, Wis.
'47 Dymond, J. R., Royal Ontario Museum of Zoology, Toronto, Ont.
'41 Earnest, Don, Bothell, Wash.
'50 Eckles, Howard H., 450-B Jordan Hall, Stanford, Calif.
'46 Eddy, Roland E., Carolina, R. I.
'47 Eddy, Samuel, University of Minnesota, Minneapolis, Minn.
'44 Eggleton, Frank E., University of Michigan, Ann Arbor, Mich.
'45 Eicher, George J., Jr., 2725 Montlake Blvd., Seattle 2, Wash.
'49 Eipper, Alfred W., 624 E. Tower Road, Ithaca, N. Y.
'47 Elkins, W. A., U. S. Fish and Wildlife Service, Juneau ,Alaska
'42 Ellis, James N., Hagerman, Idaho
'49 Ellis, T. Kenneth, Hot Springs, Va.
'49 Elser, Harold J., Dept. Research and Education, Solomons, Md.
'45 Erickson, Henry C., Battle Lake, Minn.
'49 Erickson, Jack, 406 4th St., Fairport Harbor, Ohio
'49 Erickson, Lynn, Box 727, Smithfield, Utah
'35 Erkkila, Leo, 2736 Boutista St., Antioch, Calif.
'42 Eschmeyer, Paul H., 1220 E. Washington Street, Ann Arbor, Mich.
'33 Eschmeyer, R. Wm., TVA, Norris, Tenn.
'47 Evans, Thomas R., 195 S. Cleveland Ave., St. Paul 5, Minn.
'47 Evans, Willis A., 14554 E. Hawes St. Whittier, Calif.
'47 Everhart, W. Harry, University of Maine, Orono, Me.
'49 Exelby, Kenneth W., A-21 Cedar River Park, Renton, Wash.
'49 Faber, Edward M., 7304 Pinehurst, Dearborn, Mich.
'48 Fahy, William E., Dewey Bldg., University of Rochester, Rochester 7, N. Y.
'29 Farley, John L., 719 White Building, Seattle, Wash.
'49 Fautin, Reed W., Dept. of Zoology and Physiology, University of Wyoming, Laramie, Wyo.
'28 Fearnow, Theodore C., 515 So. Washington St., Berkeley Springs, W. Va.
'42 Feast, C. N., Game and Fish Department, Denver, Colo.
'49 Felin, Frances, 450-B Jordan Hall, Stanford University, Calif.
'33 Fellers, Carl R., 52 Fearing St., Amherst, Mass.
'33 Fiedler, R. H., Economic Corp. Adm., Hotel Hallyrand, 2 Rue St., Florentin, Paris, France
'49 Fielding, James R., Jr., Box 83, Baldwin, Fla.
'31 Fish, Frederick F., Oregon State College, Corvalis, Ore.
'47 Fisher, Chas. K., Jr., Calif. Div. Fish and Game, 1842 McKinley Ave., Fresno, Calif.
'46 Fisher, Herbert J., Missouri Conservation Comm., 818 No. Garth Avenue, Columbia, Mo.
'49 Fiske, Harry T., N. Y. Conservation Dept., Crown Point, N. Y.
'45 Fitzgibbon, Mary E., Waverly Heights, Portland 2, Ore.
'49 Foran, Arthur F., 1 W. State St., Trenton, N. J.
'45 Forde, Liam, Shannon Fisheries, Thomond Weir, Limerick, Eire
'49 Fortney, Robert G., 323 Taylor Street, Jackson, Mich.

'49 Foster, Earl H., 404 S. Falls St., River Falls, Wis.
'45 Foster, Glen R., State Game Forestation and Parks Comm., State House, Lincoln, Nebr.
'46 Franett, Donald M., 8543 Latona Ave., Seattle, Wash.
'25 Frantz, Horace G., Salida, Colo.
'47 Frantz, Horace G., Jr., Box 426, Salida, Colo.
'49 Freeman, Barry O., Welaka, Fla.
'47 Frederiksen, F. M., 404 6th Ave., N.E., Faribault, Minn.
'38 Fremont, Charles, Dept. of Colonization, Mines, and Fisheries, Quebec, P. Q.
'49 Frost, Terrence P., 35 Clinton St., Concord, N. H.
'43 Fuller, Arno C., 2717 Stewart Ave., S.W., Atlanta, Ga.
'49 Fuller, Jefferson C., Jr., Box 163, Okeechobee, Fla.
'49 Fulton, Leonard A., U. S. Fish and Wildlife Service, 2725 Montlake Blvd., Seattle 2, Wash.
'40 Funk, John, Wildlife Bldg., University of Missouri, Columbia, Mo.
'48 Fuqua, C. E., Box 1306, Albuquerque, N. M.
'42 Furst, S. Dale, Jr., Box 478, Williamsport 61, Pa.
'49 Gage, James F., Route 2, Chatsworth, Ont.
'49 Galligan, James P., 1223 Forest Road, New Haven, Conn.
'49 Garlick, Lewis R., 4124 72nd Ave., N.E., Portland, Ore.
'45 Gattv, Harold. P. O. Box 929, Grand Central Sta., New York 17, N. Y.
'48 Gaufin, Arden R., Dept. Zoology and Entomology, Iowa State College, Ames, Iowa
'47 Gauley, Joseph R., U. S. Fisheries Station, Underwood, Wash.
'38 Gaver, L. W., State Fish Hatchery, Gannett, Idaho
'47 Gensch, Robert H., U. S. Fish and Wildlife Service, 1001 Fidelity Bldg., Kansas City, Mo.
'41 Gentry, Glen, 106 Penn St., Pavis, Tenn.
'45 Gerking, Shelby D., Indiana University, Bloomington, Ind
'49 German, Eugene R., General Delivery, Mt. Shasta, Calif.
'47 Gibbs, Robert C., Fisheries Research Division, Woonsocket, S. D.
'47 Gillette, Blaine T., U. S. Fisheries Station, Genoa, Wis.
'49 Gjullin, C. M., Box 332, Bureau of Ent. and Plant Quar., Corvallis, Ore.
'36 Goldie, William, 24 Strath Ave., Toronto, Ont.
'45 Gomes, Alcides L., Dept. da Producao Animal, Avenida Auga Branca, Sao Paulo, Brazil
'42 Goodwin, Harry A., 27 Grove St., Merrimac, Mass.
'46 Gosline, William A., III, University of Hawaii, Honolulu 10, T.H.
'38 Gottschalk, John S., 527 Cook Ave., Billings, Mont.
'32 Gowanloch, James Nelson, Dept. Wildlife and Fisheries, Civil Courts Bldg., New Orleans 16, La.
'49 Graham, Joseph James, 168 Montrose Ave., Toronto, Ontario, Canada
'27 Greeley, John R., New York Conservation Dept., Albany, N. Y.
'49 Green, Percy, Twin Falls, Idaho
'38 Greenbank, John, 603 S. 7th St., LaCrosse, Wis.
'47 Greene, A. F. C., Game and Fish Comm., Box 335, Cheyenne, Wyo.
'29 Greene, C. Willard, N. Y. State Conservation Dept., Albany, N. Y.
'49 Greene, Howard T., Brook Hill Farm, Genesee Depot, Wis.
'47 Grenies, Elwood D., State Fish Hatchery, Hagerman, Idaho
'49 Grim, John S., Route 3, Bushwick Rd., Poughkeepsie, N. Y.
'45 Gudjonsson, Thor V., Box 754, Reykjavik, Iceland
'49 Gunter, Gordon, Inst. Marine Science, Univ. of Texas, Port Arkansas, Texas
'49 Gustafson, Ben W., State Fish Hatchery, Route 6, Duluth, Minn.
'38 Gutermuth, C. R., Wildlife Management Institute, Investment Bldg., Washington 5, D. C.
'39 Gutsell, James S., U. S. Fish and Wildlife Service, Kearneysville, W. Va.
'49 Gwidt, Leo T., 305 Main St., Stevens Point, Wis.

'49 Hackel, Emanual, Michigan State College, East Lansing, Mich.
'49 Hadland, George S., Wisconsin Conservation Dept., Madison 4, Wis.
'48 Haevers, Don, 116 Regent Street, Lansing 12, Mich.
'47 Hagen, William, Jr., 600 Weatherly Bldg., Portland 14, Ore.
'50 Hale, Arthur S., 716 E. 72nd Terrace, Kansas City 5, Mo.
'48 Hale, John G., 2101 Knapp Ave., St. Paul 8, Minn.
'27 Halferty, G. P., 513 Coleman Bldg., Seattle 4, Wash.
'47 Hall, Albert E., Jr., Box 22, Storrs, Conn.
'49 Hall, C. E., Jr., Game and Fresh Water Fish Comm., Tallahassee, Fla.
'49 Hall, Gordon E., Dept. of Zoology, University of Oklahoma, Norman, Okla.
'48 Hall, Warren E., U. S. Fish and Wildlife Service, Washington 25, D.C.
'47 Hallock, Richard J., P. O. Box 256, Del Paso Heights, Calif.
'49 Hamilton, J. A. R., International Pacific Salmon Fisheries Comm., New Westminster, B. C.
'47 Hammond, James F., Marion, Mont.
'45 Hamre, Christopher J., University of Hawaii, P. O. Box 18, Honolulu 10, T. H.
'49 Handwerk, Paul S., U. S. Fish and Wildlife Service, Div. of Game-Fish and Hatcheries, Carterville, Ill.
'10 Hansen, Ferdinand, 480 Lexington Ave., New York, N. Y.
'28 Harkness, William J. K. Dept. of Lands and Forests, Toronto, Ont.
'47 Harmon Creek Coal Corp., 1606 First National Bank Bldg., Pittsburgh 22, Pa.
'49 Harris, Brady, Synder, Okla.
'46 Harrison, A. Cecil, 73 St. George's St., Cape Town, South Africa
'49 Harrison, Harry M., Madrid, Iowa
'47 Harry, George V., Ozark Fisheries, Stoutland, Mo.
'44 Harry, George Y., Jr., Route 3, Box 3, Astoria, Ore.
'46 Harry, Robert R., Jr., 1405 Broadway, Burlingame, Calif.
'49 Hart, J. L., Pacific Biological Station, Nanaimo, B. C.
'42 Hart, W. Bregy, 2205 Anthony Ave., Broomall, Pa.
'49 Hartt, Allan C., 2002 25th Place South, Seattle 44, Wash.
'35 Haskell, David C., State Fish Hatchery, Rome, N. Y.
'44 Haskell, William L., Box 4144, Los Angeles 24, Calif.
'42 Hasler, Arthur D., University of Wisconsin, Madison, Wis.
'45 Hassler, William W., Dept. of Zoology, University of Tennessee, Knoxville, Tenn.
'47 Hauck, Forrest R., Box 116, Meridian, Idaho
'34 Hawes, Hon. Harry B., Transportation Bldg., Washington 6, D. C.
'48 Hayes, Edward C., Jr., P. O. Box 3, Wickford, R. I.
'49 Hayes, F. Ronald, Zoological Laboratory, Dalhousie University, Halifax, N.S.
'04 Hayford, Charles O., State Fish Hatchery, Hackettstown 275, N. J.
'49 Hays, Raymond, 516 W. Main St., Bozeman, Mont.
'36 Hazard, T. P., Peace Dale, R. I.
'29 Hazzard, A. S., 1015 Packard St., Ann Arbor, Mich.
'39 Heacox, Cecil, N. Y. State Conservation Dept., Millbrook, N. Y.
'49 Hendricks, Lawrence J. Box 859, Boulder, Colo.
'41 Henn, Arthur W., Carnegie Museum, Pittsburgh, Pa.
'47 Hensley, J. D., Kleberg, Texas
'46 Herald, Earl S., California Academy of Science, Golden Gate Park, San Francisco 18, Calif.
'44 Herman, Elmer, Nevin Fish Hatchery, Route 3, Madison, Wis.
'47 Herman, John C., J. C. Herman and Company, New Cumberland, Pa.
'49 Herndon, G. B., 812 E. Capital Ave., Jefferson City, Mo.
'33 Herrington, W. C., Nat'l Resources Sec., GHQ, SCAP, APO 500 % Postmaster, San Francisco, Calif.
'40 Hess, A. D., U. S. Public Health Service, Box 769, Savannah, Ga.
'48 Hess, Ray H., 215 E. 19th St., Denver, Colo.
'48 Hewitt, George S., Box 1381, Billings, Mont.

'40 Hewitt, Harold H., Burney Creek Hatchery, Burney, Calif.
'45 Heydecker, Wayne D., 415 Lexington Ave., New York, N. Y.
'45 Hiatt, Robert W., University of Hawaii, Honolulu, T. H.
'33 Higgins, Elmer, U. S. Fish and Wildlife Service, Washington 25, D. C.
'33 Hile, Ralph, 1220 E. Washington Street, Ann Arbor, Mich.
'39 Hills, A. P., P. O. Box 299, St. John, N. B.
'47 Hiner, Laurence E., P. O. Box 1381, Billings, Mont.
'49 Hinkley, B. A., Phelps, Wis.
'49 Hirschhorn, George, 303 26th Ave., Seattle 22, Wash.
'50 Hobbins, John S., 1 N. Pinckney St., Madison 3, Wis.
'23 Hogan, Joseph R., State Fisheries, Lonoke, Ark.
'47 Holland, Gilbert A., University of Washington, Seattle, Wash.
'49 Horak, Gustave J., R.F.D. 1, Pennsylvania Run, Pa.
'47 Horn, Arthur G., 3204 21st Ave., S., Minneapolis, Minn.
'34 Hosley, N. W., U. S. Fish and Wildlife Service, Washington 25, D. C.
'46 Howard, H. C., State Fish Hatchery, North Platte, Nebr.
'24 Howley, Thomas, 2482 Tiebout Ave., New York 58, N. Y.
'20 Hubbs, Carl L., Scripps Institute of Oceanography, LaJolla, Calif.
'49 Hubbs, Clark, Dept. of Zoology, University of Texas, Austin, Texas
'47 Hueske, Edward E., U. S. Fish and Wildlife Service, Glenn Bldg., Atlanta, Ga.
'49 Huet, Marcel, Jr., Section d'Hydrobiologie, Station de Recherches des Eaux et Forêts, Groenendaal, (Hoeylaert) Belgium
'49 Hughes, Basil V., Rifle River Area, Lupton, Mich.
'49 Huish, Melvin T., Welaka, Fla.
'48 Hult, Joran, Board of Fisheries and Fisheries Research, Bix 2126, Gothenberg, Sweden
'46 Hunt, Burton P., University of Miami, Miami, Fla.
'50 Hunt, Douglas, Wautoma, Wis.
'50 Hunt, L. T., State Fish Hatchery, Macks Inn, Idaho
'13 Huntsman, A. G., University of Toronto, Toronto 5, Ont.
'49 Hutchinson, Samuel J., U. S. Fish and Wildlife Service, Swan Island, Portland 18, Ore.
'47 Indridason, Ottar, Bruum, S. Ping, Iceland
'37 Inland Fisheries Officer, P.O. Box 389, Pietermaritzburg, Natal, South Africa
'49 Irving, Robert B., Island Park, Ida.
'47 Iyengar, H. D. R., K. R. Extension, Hassan Mysore, India
'33 Jackson, Charles E., National Fisheries Institute, Victor Bldg., Washington 1, D. C.
'47 Jackson, H. W., Biology Dept., V.P.I., Blacksburg, Va.
'49 Jaeger, Wm. D., 116 Chestnut St., Chilton, Wis.
'28 James, Milton C., U. S. Fish and Wildlife Service, Washington 25, D. C.
'49 Janssen, John F., Jr., 2003 Madison Ave., Redwood City, Calif.
'47 Janzen, Daniel H., 608 Russell Ave. S., Minneapolis, Minn.
'49 Jewett, Stanley G., Jr., 7736 S.E. 20th St., Portland 2, Ore.
'49 Jhingran, V. G., 27 Chowringhi St., Calcutta, India
'33 Jobes, Frank W., Yankton College, Yankton, S. D.
'49 Joeris, Leonard, Div. of Game and Fish, Frankfort, Ky.
'48 John, V., Director of Fisheries, Madras, India
'49 Johnson, Donald R., Oregon Fish Comm., Route 1, Box 31A, Clackamas, Ore.
'49 Johnson, Fred W., U. S. Forest Service, Missoula, Mont.
'36 Johnson, Harlan E., U. S. Fish and Wildlife Service, Route 1, Box 829, Anderson, Calif.
'49 Johnson, Herbert C., Nevin State Fish Hatchery, Route 3, Madison, Wis.
'47 Johnson, Leon D., 113 Summit Ave., Spooner, Wis.
'41 Johnson, Raymond E., Dept. of Conservation, St. Paul 1, Minn.
'48 Johnson, Robt. R., Box 564, College Station, Brooking, S. D.
'47 Johnson, Wendell L., Box 1381, Billings, Mont.

'49 Jones, Richard O., Staff House No. 2, I.O.P., Carbondale, Ill.
'48 Jorgensen, J. L., P. O. Box 100, Three Rivers, P. Q.
'48 Joslin, Verne E., Dept. of Research and Development, State Capitol, St. Paul, Minn.
'46 Jossy, Wilfred E., 101 E. Greenwood St., Bend, Ore.
'49 June, Fred C., P. O. Box 2777, Honolulu, T. H.
'48 Kask, John Laurence, 1201 Conn. Ave., N.W., Washington 6, D. C.
'49 Kathrein, Joseph, 79 Cedar, Bozeman, Mont.
'18 Kauffman, R. M., The Star, Washington 4, D. C.
'49 Keenert, Ward, Wyoming Game and Fish Comm., Cheyenne, Wyo.
'47 Kelly, George F., Chesapeake Biol. Lab., Solomons, Md.
'49 Kelly, Duane K., Box 328, Rt. 3, Chino, Calif.
'44 Kelly, Homer F., P. O. Box 902, Yakima, Wash.
'28 Kemmerich, Alphonse, U. S. Fish and Wildlife Service, Swan Island, Portland 18, Ore.
'12 Kemmerick, Joseph, P. O. Box 232, Sedro-Wolley, Wash.
'49 Kennedy, H. B., 1708 Farnam St., Omaha 3, Nebr.
'41 Kennedy, W. A., 212 Pinedale Ave., St. Boniface, Man.
'41 Kibbee, T. S., U. S. Fish and Wildlife Service, Plymouth Bldg., Minneapolis, Minn.
'47 Kilgus, H. E., Brockway, Pa.
'38 King, Willis, Tennessee Game and Fish Commission, 166 8th Ave. North, Nashville, Tenn.
'48 Kinney, Charles W., 3743 Appleton St. N.W., Washington 16, D. C.
'48 Kleerekoper, Herman, McMaster University, Hamilton, Ont.
'42 Klein, William D., 851 S. Windemere, Littleton, Colo.
'49 Klick, Thomas A., Northwest Fisheries Area, Spooner, Wis.
'48 Knapp, Frank T., Box 254, Dept. of Wildlife Management, Texas A and M College, College Station, Texas
'49 Kohl, C. A., 103 W. Fond du Lac, Ripon, Wis.
'45 Kolbe, Carl F., Port Dover, Ont.
'49 Koo, Ted S. Y., School of Fisheries, Universty of Washington, Seattle 5, Wash.
'35 Koster, William J., University of New Mexico, Albuquerque, N. M.
'47 Krefting, Laurits, University Farm, St. Paul 1, Minn.
'47 Kruger, Hans W., Box 425, Saint James, Minn.
'43 Krumholz, Louis A., Indiana University, Bloomington, Indiana
'33 Kuehl, Eric O., U. S. Fish and Wildlife Service, Underwood, Wash.
'49 Kuehn, Jerome H., Box 202, Willernie, Minn.
'49 Kulkarni, C. V., Old Custom House, Bombay I, India
'42 Kurrus, Theodore, Dutchess Valley Club, Pawling, N. Y.
'49 Kutschenreuter, W. H., Route 1, Oconomowoc, Wis.
'48 Laakso, Martin, R.R. 1, Fulton, Mo.
'42 Lachner, Ernest A., Div. of Fishes, U. S. National Museum, Washington, D. C.
'49 LaMonte, Francesca, American Museum of Natural History, New York 24, N. Y.
'47 Lanberton, Robert, Box 789, Franklin, Pa.
'49 Landen, Orville, Wyoming Game and Fish Comm., Cheyenne, Wyo.
'49 Lane, Raymond J., Sebago Hatchery, Raymond, Me.
'25 Langlois, T. H., P. O. Box C, Put-in-Bay, Ohio
'48 Larimore, Weldon R., Illinois National History Survey, Urbana, Illinois
'29 Larsen, Henry A., State Fish Hatchery, Hayward, Wis.
'49 Larson, Ralph, Washington State Game Dept., 1601 Simpson, Aberdeen, Wash.
'50 Lawler, G. Herbert, Apt. 12, 98 Charles St. E., Toronto, Ont.
'41 Lawrence, William M., 30 Main St., Saranac Lake, N. Y.
'08 Lay, Charles E., Railroad St. Ft. of Wayne St., Sandusky, Ohio
'49 Laythe, Leo L., U. S. Fish and Wildlife Service, Swan Island, Portland 18, Ore.
'50 Lee, Donald R., P. O. Box 1116, Westwood, Calif.
'47 Leffler, Ross L., 1104 Carnegie Bldg., Pittsburgh 30, Pa.

'49 Legendre, Vianney, Quebec Biological Bureau, U'634 Université de Montreal, Montreal 26, P.Q.
'48 Lehti, Robert W., 1530 Sherman St., Denver 5, Colo.
'25 Leim, A. H., Box 254, St. Andrews, N. B.
'47 Lenz, Gerhard, State Fish Hatchery, Gretna, Nebr.
'49 Leonard, John P., Cuprinol Division, Darworth, Inc., Simsbury, Conn.
'35 Leonard, Justin W., University Museums Annex, Ann Arbor, Mich.
'47 Lesher, S. W., 303 N. 17th St., Corvallis, Oregon
'36 Lewis, R. C., 2316 Normal Ave., Fresno, Calif.
'47 Lewis, William M., Sr., Zoology Dept., Southern Illinois Univ., Carbondale, Ill.
'49 Lievense, Stanley, Dept. of Conservation, Baldwin, Mich.
'49 Lindaman, Harry R., Fairmount Park Aquarium, Fairmount Park, Philadelphia 30, Pa.
'33 Lindner, Milton J., American Embassy, Mexico, D. F. Mexico
'49 Lipschuetz, Morris, 383 E. Main St., Rochester 4, N. Y.
'49 Liscom, Kenneth L., U. S. Fisheries Station, Los Molinos, Calif.
'45 Little, Gordon Scott, Old Armory, Cornell University, Ithaca, N. Y.
'49 Littleford, Robert A., Dept. of Zoology, University of Maryland, College Park, Md.
'38 Lloyd, Charles N., Wisconsin Conservation Dept., State Office Bldg, Madison 2, Wis.
'49 Loeb, Howard A., 9 Birch Road, Yonkers, N. Y.
'49 Lopez, Juan V., Binmaley, Pangasinan, P. I.
'47 Louchet, C., Syndicat des Pisciculteurs de France, Wailly Par Conty, Somme, France
'47 Lowry, Edward M., Dept. Zoology, Mich. State College, East Lansing, Mich.
'33 Lucas, Clarence R., 2479 Barrington Ave., Los Angeles 34, Calif.
'43 Lyman, F., Earle, 42 Hilldale Dr., Decatur, Ga.
'38 Lynch, James E., University of Washington, Seattle 5, Wash.
'26 MacKay, H. H., East Block, Parliament Bldgs., E. 137, Toronto, Ont.
'47 Mackenthun, Kenneth M., 3717 Ross St., Madison, Wis.
'49 Maclay, David J., 828 Ronald Ave., Missoula, Mont.
'42 MacRae, Joseph W., 2311 16th Ave., Seattle 2, Wash.
'48 Madsen, M. J., 2635 Dearborn St., Salt Lake City, Utah
'49 Maloney, John E., Fisheries Research Unit, 355 Schubert Bldg., St. Paul, Minn.
'49 Maltzeff, Eugene M., 6041 4th N.E., Seattle 5, Wash.
'47 Mané, Andres M., School of Fisheries, University of Washington, Seattle, Wash.
'45 Marr, John C., 450-B Jordan Hall, Stanford University, Palo Alto, Calif.
'41 Marshall, Nelson, Virginia Fisheries Laboratory, Yorktown, Va.
'49 Martin, J. Mayo, Dept. of Zoology, University of Oklahoma, Norman, Okla.
'48 Martin, William R., Atlantic Biological Station, St. Andrews, N. B.
'49 Marvich, Edward S., Wash. State Game Dept., 6535 6th Ave. N.W., Seattle, Wash.
'45 Mason, E. D., U. S. Fisheries Station, Crawford, Nebr.
'49 Mason, Wm. E., Dept. of Conservation, Imlay City, Mich.
'49 Massmann, Wm. H., Va. Fisheries Laboratory, Yorktown, Va.
'47 Mastin, Henry E., General Delivery, Gold Beach, Ore.
'21 Matthews, J. H., 1 Fulton Fish Market, New York, N. Y.
'47 Maxfield, Galen H., Dept. of Research and Education, Solomons, Md.
'44 McCabe, Britton, Springfield College, Springfield 9, Mass.
'49 McCamey, B. Franklin, Jr., Box U-67, Storrs, Conn.
'49 McClane, A. J., Fishing Editor, Field and Stream, 515 Madison Ave., New York, N. Y.
'48 McConnell, C. R., State Fish Hatchery, Valley Ranch, N. M.
'49 McCutchin, Thayre, Nevin Fish Hatchery, Route 3, Madison, Wis.
'49 McGaha, Young John, Zoology Dept., Univ. of Mich., Ann Arbor, Mich.
'44 McGraw, Max, 120 S. LaSalle St., Chicago, Ill.
'30 McKenzie, R. A., Box 233, Chatham, N. B.
'49 McKernan, Donald L., 4032 11th N.E., Seattle, Wash.

'20 McKinney, Robert E., 16 Rosecliff St., Roslindale, Mass.
'29 Meehean, O. Lloyd, U. S. Fish and Wildlife Service, Washington 25, D. C.
'49 Meigs, Robert C., Washington State Game Dept., 509 Fairview Ave. N., Seattle, Wash.
'42 Menzel R., Winston, Texas A. and M. Research Foundation, College Station, Texas
'49 Merrell, Theodore R., 7201 Lake Road, Milwaukie, Ore.
'41 Methisen, Leonard M., Box 63, Reedsport, Ore.
'49 Millenbach, Cliff, 515 Smith Tower, Seattle 4, Wash.
'49 Miller, Harold S., Twin Falls, Idaho
'38 Miller, Lawrence F., Box 532 TVA, Decatur, Ala.
'41 Miller, Richard B., University of Alberta, Edmonton, Alberta
'49 Miller, Richard Gordon, 1319 Hopkins Ave., Palo Alto, Calif.
'44 Miller, Robert R., University Museums, Ann Arbor, Mich.
'47 Miller, Sidney C., Hartman Creek State Fish Hatchery, Waupaca, Wis.
'49 Mills, Harlow B., Ill. Natural History Survey, 132 Natural Resources Bldg., Urbana, Ill.
'48 Mitra, G. N., Dept. of Fisheries, P. O. Cuttack, Orissa, India
'49 Moffett, James, 1220 E. Washington Street, Ann Arbor, Mich.
'47 Moltz, Harold, 320 Grampian Blvd., Williamsport, Pa.
'31 Moody, Ervin, State Rearing Ponds, Route 1, Hillsdale, Mich.
'48 Moody, Tom, State Fish Hatchery, Jemez Springs, N. M.
'18 Moore, Emmeline, Slingerlands, N. Y.
'38 Moore, George Azro, Oklahoma A and M College, Stillwater, Okla.
'50 Moore, Harvey L., Pacific Oceanic Fishery Investigations, P.O. Box 3830, Honolulu, T.H.
'49 Moorman, Robert B., Dept. of Zoology and Entomology, Iowa State College, Ames, Iowa
'44 Morrow, James E., Jr., Box 2025 Yale Sta., New Haven, Conn.
'42 Morton, William M., U. S. Fish and Wildlife Service, Swan Island, Portland 18, Oregon
'47 Mosbaugh, Harrel F., Box 1381, Billings, Mont.
'45 Moss, Douglas D., W. Willington, Conn.
'43 Moss, Robert H., Storrs, Conn.
'35 Mottley, C. McC., U. S. Fish and Wildlife Service, Washington 25, D. C.
'43 Moyle, John B., Dept. of Conservation, St. Paul, Minn.
'43 Murphy, Garth, North Rotunda, Museum Bldg., Stanford University, Calif.
'48 Murray, Leo T., Box 138, Billings, Mont.
'37 Myers, George S., Natural History Museum, Stanford University, Calif.
'49 Myhre, Richard J., Rt. 2, Box 2018-T, Edmonds, Wash.
'31 Nachman, Fred, Park Rapids, Minn.
'49 Neave, Ferris, Pacific Biological Station, Nanaimo, B. C.
'28 Needham, Paul R., Zoology Dept., University of California, Berkeley, Calif.
'47 Nelson, Bennel, Centerton, Ark.
'43 Neville, William C., U. S. Fisheries Lab., Milford, Conn.
'38 Newcomb, Hugh Ross, P. O. Box 451, Roseberg, Ore.
'42 Newcombe, Curtis L., U. S. Public Health Service, 630 Sansome St., San Francisco, Calif.
'45 Nicholas, Lester E., State Fish Hatchery, Verdi, Nev.
'38 Norris, Russell T., 50 Milk St., Newburyport, Mass.
'50 Nursall, J. R., Dept. of Biology, Univ. of Saskatchewan, Saskatoon, Sask., Can.
'49 Obregon, Fernando, Coahuilo 221-12, Mexico City, Mex.
'29 Odell, Theodore, Hobart College, Geneva, N. Y.
'38 O'Donnell, D. John, 830 State Office Bldg., Madison 2, Wis.
'42 Oehmcke, Arthur, State Fish Hatchery, Woodruff, Wis.
'49 Oilschlager, Ellsworth, 420 Island Ave., Port Edwards, Wis.
'45 Ordway, J. G., Cedar Island Hatchery, St. Paul 1, Minn.

'47 Orgchangco, Bayani, Philippine School of Fisheries, Navotas, Rizal, P. I.
'40 Otis, James C., Jr., 45 High Street, Newburyport, Mass.
'49 Ott, Emil, J. N., Jr., 545 Harbor Blvd., Belmont, Calif.
'49 Owen, John B., U. S. P. H. S. Environmental Health Center, Cincinnati, Ohio
'49 Padlan, Pedro G., Mandurriao, Iloilo City, P. I.
'44 Paget, Richard, Hillville Cologhane Castlegregory, Co. Kerry, Eire
'49 Parker, Robert R., Washington State Fisheries Dept., 1308 Smith Tower, Seattle, Wash.
'49 Parkhurst, Z. E., U. S. Fish and Wildlife Service, Seattle, Wash.
'45 Parr, Sam A., 1639 E. Main St., Decatur, Ill.
'49 Pasko, Donald C., 383 E. Main St., Rochester 7, N. Y.
'48 Patriarche, Merces H., Missouri Conservation Comm., Wildlife Bldg., Columbia, Mo.
'37 Patterson, Matt, 415 S. Third Ave., Sturgeon Bay, Wis.
'49 Pautzke, Clarence F., 2124 W. 99, Seattle, Wash.
'49 Pechacek, Louis S., College Housing, Prefab 1404, Logan, Utah
'49 Peck, Wm. L., Office of River Basin Studies, Fish and Wildlife Service, Swan Island, Portland 18, Ore.
'23 Pells, Frank, Cultus Lake E., B. C.
'28 Pelnar, John, Box 829, Anderson, Calif.
'38 Pelton, John Z., 205 First Ave., Waverly, Ohio
'47 Pennak, Robert W., University of Colorado, Boulder, Colo.
'38 Perlmutter, Alfred, 48-12 91St. Place, Elmhurst, Long Island, N. Y.
'49 Perrine, Burton, Mt. State Trout Growers Assoc., Twin Falls, Idaho
'39 Perry, L. Edward, Swan Island, Portland 18, Ore.
'46 Perryman, Roy, Calico Rock, Ark.
'47 Pesquera, Gilberto V., Box 3151, Santurce, Puerto Rico
'49 Peterson, A. E., International Salmon Comm., New Westminster, B. C.
'49 Peterson, Donald R., University Museums Annex, Ann Arbor, Mich.
'49 Peterson, Kenneth L., University Museums Annex, Ann Arbor, Mich.
'49 Petty, Archibald C., 226 Church St., Poughkeepsie, N. Y.
'47 Phenicie, Charles K., State Department of Fish and Game, Helena, Mont.
'42 Phillips, Arthur M., Jr., U. S. Fish and Wildlife Service, Cortland, N. Y.
'47 Phillips, G. I., Pennsylvania Game Commission, Harrisburg, Pa.
'48 Pickett, Lewis, R. 5, Lake Duncan, Duncan, Okla.
'41 Pillow, Braden, 512 Okla. Natural Bldg., Oklahoma City, Okla.
'47 Pillsbury, Harold W., Litchfield-Morris Sanctuary, Litchfield, Conn.
'48 Pintler, Herbert E., California Div. of Fish and Game, 1842 McKinley Ave., Fresno, Calif.
'42 Pitney, William E., P.O. Box 673, Florence, Ore.
'49 Piza, Joseph J., 29 Reservoir Ave., Norwalk, Conn.
'47 Posekany, Lewis, Red Granite, Wis.
'49 Pough, Richard H., American Museum of Nat'l History, Central Park West at 79th St., New York 24, N. Y.
'26 Powell, Albert M., Lewiston, Md.
'47 Power, James F., 1941 Fruit St., Westboro, Mass.
'49 Prasad, R. R., Central Marine Fisheries Sta., Mandapan Camp., South India
'46 Prashad, Baini, E. H. and L. Department, Gov't. of India, New Delhi, India
'47 Prather, E. E., Alabama Experiment Station, Auburn, Ala.
'48 Pratt, Virgil S., University Museums Annex, Ann Arbor, Mich.
'34 Prévost, Gustave, University of Montreal, Montreal, P. Q.
'32 Pritchard, A. L., Dept. of Fisheries, West Block, Ottawa, Ont.
'47 Proffitt, Max A., Dept. of Zoology, University of Michigan ,Ann Arbor, Mich.
'49 Purkett, Charles, 522 West Main, Bozeman, Mont.
'47 Rabanal, Herminio R., Bureau of Fisheries, Manila, P. I.
'49 Raith, Walter L., 12 Glenridge Rd., Katonah, N. Y

'38 Raney, Edward C., Cornell University, Ithaca, N. Y.
'47 Rasalan, Santos, Division of Fisheries, Navotas, Rizal, P. I.
'49 Rawson, D. S., University of Saskatchewan, Saskatoon, Sask.
'37 Rayner, John H., 1634 S. W. Alder St., Portland 8, Ore.
'40 Reavley, William L., Jr., State Fish and Game Department, Helena, Mont.
'47 Redhead, Hugh, Coleman Lake Club, Goodman, Wis.
'43 Reid, Cecil W., The Lake Improvement Co., 104 E. 13th St., Austin, Texas
'38 Reid, Kenneth A. Whitney Industries Inc., Sabattis, N. Y.
'49 Reynolds, Henry J., Sumner, Wash.
'47 Rhoades, Rendell, 710 W. Main St., Blanchester, Ohio
'45 Richan, Fred J., P. O. Box 421, Jackson, Wyo.
'24 Richard, L. A., Dept. Colonization, Mines, and Fisheries, Quebec, P. Q.
'35 Richardson, Laurence R., Victoria University College, Wellington, New Zealand
'30 Ricker, William E., Indiana University, Bloomington, Indiana
'47 Riethmiller, Ray, 2078 Darmouth Ave., Columbus, Ohio
'44 Riggs, Carl D., Dept. of Zoology, University of Oklahoma, Norman, Okla.
'47 Ripley, William Ellis, North Rotunda, Museum Bldg., Stanford University, Calif.
'43 Rivers, Cole M., Route 1, Box 148, Grants Pass, Ore.
'47 Roberts, Floyd, Game and Fish Department, Cheyenne, Wyo.
'49 Roberts, Leo S., Roaring Gap, N. C.
'47 Roberts, Travis S., 606 First National Bank Bldg., Vicksburg, Miss.
'45 Robertson, O. H., University of Chicago, Chicago 37, Ill.
'49 Rockwell, Julius, Jr., Fisheries Research Institute, University of Washington, Seattle 5, Wash.
'49 Roecker, Robert M., Zoology Dept., Cornell University, Ithaca, N. Y.
'35 Rogers, Carleton, Mt. Whitney Hatchery, Independence, Calif.
'39 Roith, Raymond, 849 Thomas St., St. Paul, Minn.
'45 Rosa, Horacio, Jr., F.A.O. 1201 Connecticut Ave., N.W., Washington 6, D. C.
'45 Rose, Earl T., Iowa State Conservation Commission, Spirit Lake, Iowa
'47 Rosebery, Dean A., Biology Department, V.P.I., Blacksburg, Va.
'47 Roszman, Foster D., 218 W. Main St., Ottawa, Ohio
'41 Rounsefell, George A., 190 Main St., Orono, Me.
'49 Roxas, Jaime V., Marikina, Rizal, P. I.
'36 Royce, Wm. F., Woods Hole, Mass.
'40 Russel, Henry D., Springdale Ave., Dover, Mass.
'49 Russell, Ralph, U. S. Fish and Wildlife Service, Washington 25, D. C.
'40 Sadler, Charles Webb, Sandusky, Ohio
'35 Sadler, William O., Mississippi College, Clinton, Miss.
'47 Saeugling, E. C., U. S. Fisheries Station, Guttenberg, Iowa
'47 Sampson, Raymond E., U. S. Fisheries Sta., Homer, Minn.
'49 Sarbahi, D. S., 4039 12th N.E., Seattle 5, Wash.
'49 Sarenas, Artemio V., Hopkins Marine Station, Pacific Grove, Calif.
'49 Sawyer, Philip J., 2735 S. Wagner Rd., Ann Arbor, Mich.
'39 Scattergood, Leslie W., U. S. Fish and Wildlife Service, Booth Bay, Me.
'50 Schacht, John R., 604 W. Olney Ave., Philadelphia 20, Pa.
'38 Schaefer, Milner B., U. S. Fish and Wildlife Service, P. O. Box 3830, Honolulu, T.H.
'47 Schleicher, William A., Division of Game and Fish, Frankford, Ky.
'47 Schley, Benjamin H., Richland, Mo.
'49 Schloemer, Clarence Louis, 131 Natural Science Bldg., Michigan State College, East Lansing, Mich.
'35 Schotam, Joseph B., 1818 Ford Bldg., Detroit 26, Mich.
'50 Schmid, James F., 1611 Ruddiman Ave., N. Muskegon, Mich.
'47 Schmidt, Arthur, High Pond Farms, Brandon, Vt.
'35 Schneberger, Edward, Conservation Department, Madison 2, Wis.
'49 Schoning, Robert W., Oregon Fish Comm., R. 1, Box 31A, Clackamas, Ore.

'39 Schuck, Howard A., U. S. Fish and Wildlife Service, Woods Hole, Mass.
'35 Schultz, Leonard P., U. S. National Museum, Washington 25, D. C.
'50 Schumacher, Robert E., 2599 N. Lexington Ave., St. Paul 8, Minn.
'49 Schumacher, Wm., 134 N. E. 16th St., Oklahoma City, Okla.
'15 Scofield, N. B., 430 Kingsley Ave., Palo Alto, Calif.
'33 Scofield, W. L., State Fisheries Laboratory, Terminal Island, Calif.
'49 Scott, Brown Wood, P. O. Box 870, Ardmore, Okla
'44 Scott, Donald C., University of Georgia, Athens, Ga.
'38 Scott, John W., University of Wyoming, Laramie, Wyo.
'49 Scott, Walter E., Wisconsin Conservation Dept., Madison 2, Wis.
'49 Scruggs, George D., Jr., State Fish Hatchery, Route 5, Morgantown, N. C.
'50 Scully, James A., RFD 1, Box 700 H. Marquette, Mich.
'46 Seaman, Elwood A., 270 Oakwood Rd., Charleston 4, W. Va .
'48 Seaman, W. R., 5377 Columbine Rd., Denver 11, Colo.
'47 Sears, Nicholas J., U. S. Fisheries Station, LaCrosse, Wis.
'30 Senning, W. C., N. Y. Conservation Department, Albany, N. Y.
'23 Sette, Oscar E., U. S. Fish and Wildlife Service, P.O. Box 38, Honolulu, T. H.
'45 Seymour, Allyn, Fisheries Hall No. 2, University of Washington, Seattle 5, Wash.
'46 Shapiro, Sidney, U. S. Fish and Wildlife Service, Washington 25, D. C.
'34 Shapovalov, Leo, Bureau of Fish Conservation, Ferry Bldg., San Francisco, Calif.
'49 Sharma, Surendra, Fisheries Dept., Govt. of Bihar, Patna, India
'47 Sharp, Robert W., 138 E. Winifred St., St. Paul 7, Minn.
'46 Sheen, Hann-shyang, Div. of Fishery, Ministry of Agriculture, Nanking, China
'37 Shetter, David S., Box 5, Lewiston, Mich.
'42 Shields, A. Randolph, Waynesville, N. C.
'44 Shoemaker, Hurst H., University of Illinois, Urbana, Ill.
'39 Shoup, Chas. S., Vanderbilt University, Box 77, Nashville 4, Tenn.
'43 Sigler, William F., Utah State Agricultural College, Logan, Utah
'35 Simon, James R., Jackson Hole, Wildlife Park, Moran, Wyo.
'49 Simpson, Don G., Box 5276, College Station, Texas.
'38 Simpson, James C., Idaho Fish and Game Dept., Boise, Idaho
'49 Sjoberg, Elliott S., 828 Farrar St., Cadillac, Mich.
'49 Skaggs, Lutherf G., State Fish Hatchery, Marion, N. C.
'44 Slater, Daniel W., U. S. Fish and Wildlife Service, Signal Depot, Sacramento, 14, Calif.
'49 Sleeper, David A., Box 196, Anchorage, Alaska
'48 Smedley, S. C., Prairie Creek Fish Hatchery, Orick, Calif.
'49 Smith, Arthur L., Jr., P.O. Box 1153, Bryan, Texas
'49 Smith, Bernard R., P. O. Box 128, Cheboygan, Mich.
'49 Smith, G. F. M., Univ. of New Brunswick, Fredericson, N.B.
'38 Smith, Lloyd L., Jr., 300 Administration Bldg., University Farm, St. Paul 1, Minn.
'33 Smith, M. W., Atlantic Biological Station, St. Andrews, N. B.
'49 Smith, Marvin, 530 25th Ave., Langwien, Wash.
'31 Smith, Osgood R., 450-B Jordan Hall, Stanford University, Calif.
'44 Smith, Robert O., Box 451, Beaufort, S. C.
'44 Smith, Stanford H., 1220 E. Washington Street, Ann Arbor, Mich.
'35 Smyth, J. Adger, Salem, Va.
'47 Snieszko, Stanislas F., U. S. Fish and Wildlife Service, Kearneysville, W. Va.
'47 Solman, Victor E. F., Dominion Wildlife Service, Ottawa, Ont.
'37 Speaker, E. B., 10th & Mulberry Sts., Des Moines, Iowa
'16 Spragle, L. H., Paradise Brook Trout Co., Cresco, Pa.
'40 Sprecher, George E., Wisconsin Conservation Dept., Madison 2, Wis.
'38 Springer, Stewart, Box 144, Stuart, Fla.
'49 Sprugel, George, Zoology Dept., Iowa State College, Ames, Ia.
'10 Stack, George F., Paradise Brook Trout Co., Cresco, Pa.

'37 Stapledon, Chas. F., Fish Culture Branch, Dept. of Fisheries, Ottawa, Ont.
'49 Starr, Donald F., 256 N. Mountain Ave., Montclair, N .J.
'47 Starrett, Wm. C., Illinois Natural History Survey Lab., Havana, Ill.
'49 Steele, Raymond E., 724 9th St., N.W., Washington, D. C.
'47 Steen, Melvin O., Conservation Commission, Jefferson City, Mo.
'49 Stefanich, Frank A., 25 Beech Street, Bozeman, Mont.
'47 Stenton, James E., P. O. Box 19, Banff, Alberta
'48 Stephens, Robert F., 238 Truslow St., Charleston, W. Va.
'47 Stewart, R. A., U. S. Fisheries Station, Rochester, Ind.
'49 Stinauer, Rudolph F., University Museums Annex, Ann Arbor, Mich.
'35 Stobie, George J., State House, Augusta, Me.
'46 Stoddard, James V., Philwold, St. Joseph's, New York
'49 Stohl, Donald D., 59 N. Welles Drive, Newington, Conn.
'47 Stoltz, William J., U. S. Fisheries Station, LaCrosse, Wis.
'42 Stone, Fred L., 95 Troup St., Rochester, N. Y.
'36 Stone, Udell B., 303 Troy Rd., Rochester 10, N. Y.
'44 Stringer, Louis D., Woods Hole, Mass.
'49 Stroud, G. Luhrs, 1218 N. Rolfe St., Arlington, Va.
'43 Stroud, Richard H., Phillips Wildlife Research Lab., Upton, Mass.
'39 Sumner, H. Francis, Sandlake, Oregon
'26 Surber, Eugene W., U. S. Fish and Wildlife Service, Kearneyville, W. Va.
'49 Suttkus, Royal D., Stimson Hall, Cornell University, Ithaca, N. Y.
'47 Swanson, Gustave A., Fernow Hall, Cornell Univ., Ithaca, N.Y.
'41 Swartz, Albert H., 26 Grover Rd., Medford, Mass.
'47 Swasey, Paul E., Conservation Commission, Elkins, W. Va.
'47 Swem, Theodor R., 1476 Penn Street, Denver, Colo.
'49 Swenson, Hjalmar, Minnesota Dept. of Conservation, St. Paul 1, Minn.
'35 Swingle, H. S., Alabama Experiment Station, Auburn, Ala.
'43 Tack, Peter I., Michigan State College, East Lansing, Mich.
'34 Taft, Alan C., Division of Fish and Game, Ferry Bldg., San Francisco, Calif.
'39 Talbott, Leon A., Mt. Whitney Hatchery, Independence, Calif.
'49 Tanner, Howard A., 3328 E. Michigan Ave., Lansing, Mich.
'34 Tarzwell, Clarence M., U.S. Public Health, E. 3rd and Kilgour Sts., Cincinnati 2, O.
'49 Taube, Clarence M., University Museums Annex, Ann Arbor, Mich.
'30 Taylor, B. W., McGill University, Montreal, P. Q.
'47 Taylor, William Ralph, University of Michigan, Ann Arbor, Mich.
'42 Templeman, Wilfred, Government Laboratory, St. John's, Newfoundland
'19 Terrell. Clyde B., Oshkosh, Wis.
'42 Terrill, Harold V., Route 1, Ashland, Mo.
'30 Tester, Albert L., Univ. of Hawaii, Honolulu 14, T. H.
'13 Thomas, Adrian, Box 63, Harbor Beach, Mich.
'49 Thomas, Colin J. S., Club Rd., Ruxton 4, Md.
'26 Thomas, R. P., 1621 Kemble St., Utica, N. Y.
'50 Thompson, Clark S., 7003 34th Ave. N.W., Seattle 7, Wash.
'35 Thompson, Fred A., Department of Game and Fish, Santa Fe, N. M.
'36 Thompson, Seton H., U. S. Fish and Wildlife Service, Washington, D. C.
'18 Thompson, W. F., Fisheries Research Inst., University of Washington, Seattle 5, Wash.
'47 Thompson, William H., P. O. Box 386, North Campus, University of Oklahoma, Norman, Okla.
'36 Thorpe, Lyle M., State Board of Fisheries and Game, Hartford, Conn.
'49 Threinen, C. W., N. E. Fishery Area Hdqtrs., Woodruff, Wis.
'49 Thurston, Donald B., Box 184, Wells, Nevada
'13 Tichenor, A. K., 111 California St., San Francisco, Calif.
'45 Tiller, Richard E., U. S. Fish and Wildlife Service, Woods Hole, Mass.
'39 Tingley, F. A., Customs House, St. John's N. B.

'45 Todd, Paul, 1101 E. 5th, Apt. 3, North Platte, Nebr.
'49 Tomalonis, Edward J., Fish Hatchery, R. R. No. 1, Zion Grove, Pa.
'50 Toman, Frank A., N. Y. State Conservation Dept., 856 Main St., Poughkeepsie, N. Y.
'49 Tompkins, Wm. A., Dept. of Zoology, University of Michigan, Ann Arbor, Mich.
'47 Toole, Marion, 3401 Windsor Rd., Austin, Texas
'49 Torrey, Edward P., Box 415, Benson Hall ,Univ. Truac Project, Madison 4, Wis.
'33 Trautman, Milton B., Franz Stone Laboratory, Put-in-Bay, Ohio
'48 Trelease, Thomas J., 1302 B St., Sparks, Nev.
'33 Trembley, Gordon L., State Fish Hatchery, Bellefonte, Pa.
'43 Tresselt, Ernest F., Box 812, Williamsburg, Va.
'21 Tresselt, Frederick, Box 26, Thurmont, Md.
'35 Tressler, Willis L., 4608 Amherst Rd., College Park, Md.
'20 Truitt, R. V., Chesapeake Biological Laboratory, Solomons Island, Md.
'32 Tunison, A. V., U. S. Fish and Wildlife Service, Washington 25, D. C.
'49 Tuttle, Edward M., U. S. Fisheries Station, Leavenworth, Wash.
'47 Umali, Augustin F., Philippine School of Fisheries, Navotas, Rizal, P. I.
'48 Vallentyne, J. W., 260 Johnson St., Kingston, Ont.
'43 Van Deusen, R. D., Dept. of Research and Education, Box 8, Solomons, Md.
'42 Van Engel, Willard A., Virginia Fisheries Laboratory, Yorktown, Va.
'43 Van Horn, Willis M., Institute of Paper Chemistry, Appleton, Wis.
'49 Van Hyning, Jack M., Route 3, Box 3, Astoria, Ore.
'49 Van Meter, Harry D., 525 W. South St., Greenville, Ill.
'28 Van Oosten, John, University Museums, Ann Arbor, Mich.
'47 Vaughan, Tim M., Dept. of Fish and Game, Rt. 1, Sagle, Idaho
'49 Ver Duin, Claude, 406 Howard St., Grand Haven, Mich.
'47 Videla, Pedro H. Bruno, Caza Maratima, Pasio Colin 922, Buenos Aires, Argentina
'47 Villadolid, Deogracias V., Dept. of Agriculture and Commerce, Manila, P. I.
'19 Viosca, Percy Jr., 2490 Dreux Ave., New Orleans 7, La.
'37 Vladykov, Vadim D., Dept. of Fisheries, Quebec, P.Q.
'47 Von Limbach, Bruno, House No. 41, Port Washington, Washington 20, D. C.
'49 Voskuil, Glenn, Nevin Fish Hatchery, Route 3, Madison, Wis.
'48 Walden, Francis A., Box 687, Parry Sound, Ontario
'34 Wales, J. H., Box 124, Mount Shasta, Calif.
'49 Walford, Lionel A., U. S. Fish and Wildlife Service, Washington 25, D. C.
'47 Walker, Boyd W., University of California, Los Angeles 24, Calif.
'48 Walker, John D., 406 Endowment Bldg., Urbana, Ohio
'16 Wallace, Frederick W., Gardenvale, P. Q.
'49 Wallen, Irvin E., Zoology Dept., Okla. A. and M. College, Stillwater, Okla.
'49 Wallis, Orthello, 645 Avenue M, Boulder City, Nevada
'49 Walters, Albert, 3460 N. First St., Milwaukee, Wis.
'47 Ward, David L., Hot Creek Hatchery, Bishop, Calif.
'49 Ward, H. C., State Game and Fish Dept., Oklahoma City 5, Okla.
'49 Ward, John M., R.R. 2, Box 297-A, Olympia, Wash.
'38 Warfel, Herbert, % U. S. Embassy, APO, % Postmaster, San Francisco, Calif.
'44 Warfield, Edwin, Jr., Dept. of Tidewater Fisheries, State Office Bldg., Annapolis, Md.
'47 Warren, Parker, State Fish Hatchery, St. Peter, Minn.
'40 Washburn, George N., Ozark Fisheries, Stoutland, Mo.
'40 Waters, Don, Ohio Division of Conservation, Columbus, Ohio
'49 Waters, Otis Mark, Vails Gate, N. Y.
'47 Watson, Charles H., Whitesell Trout Hatchery, Whitesell P. O. Man.
'49 Weber, K. G., U. S. Fish and Wildlife Service, 2725 Montlake Blvd., Seattle, Wash.
'38 Webster, Dwight A., N. Y. College of Agriculture, Ithaca, N. Y.
'48 Weir, J. Charles, Dept. of Lands and Forests, Lindsay, Ont.
'36 Wells, Rennie E., Jr., Wolf Creek, Mont.

'34 Wendt, L. W., Strain Bldg., Great Falls, Mont.
'41 Werner, Walter H. R., Dept. of Game and Fisheries, Toronto, Ont.
'24 Westerman, Fred A., Dept. of Conservation, Lansing, Mich.
'49 Westfall, T. D., Route 2, Box 1435, Aptos, Calif.
'47 White, Mark O., 205 N. Fifth St., Cambridge, Ohio
'49 Whiteleather, Richard T., U. S. Fish and Wildlife Service, Washington 25, D. C.
'50 Whitlock, B. G., Camdenton, Mo.
'19 Wickliff, Edward L., 2916 Harrisburg Pike, Grove City, Ohio
'43 Wiebe, Abraham, Box 493, TVA, Norris, Tenn.
'47 Wild, Earl S., State Fish Hatchery, Tensleep, Wyo.
'39 Wilding, James L., 2987 S. 7th East, Salt Lake City 6, Utah
'42 Wilimovsky, Norman J., University Museums, Ann Arbor, Mich.
'47 Williams, B. K., Box 91, E. Stroudsburg, Pa.
'49 Williams, John E., 1082 Goshen Ct., Willow Run, Michigan
'37 Williamson, Lyman O., Hayward, Wis.
'49 Willoughby, Hervey, U. S. Fish Cultural Sta., Bozeman, Mont.
'48 Winget, Russel L., 271 Madison Ave., New York 16, N. Y.
'49 Winner, Louis S., 237 W. Water St., Lock Haven, Pa.
'49 Winton, Benjamin, State Fish Hatchery, Bayfield, Wis.
'49 Wistrom, Clarence A., Wisconsin Conservation Dept., Spooner, Was.
'47 Wohlschlag, Donald E., Dept. of Biol. Sci., Stanford Univ., Stanford, Calif.
'31 Wolf, Louis E., State Fish Hatchery, Rome, N. Y.
'47 Wood, Roy K., 526 Ten Forsyth St., Atlanta 3, Ga.
'50 Woodruff, Gwyn W., Pineola, N. C.
'49 Woods, Loren P., Chicago Natural History Museum, Chicago 5, Ill.
'19 Wright, Albert, H., 113 E. Upland Rd., Ithaca, N. Y.
'47 Wuhrmann, Karl, Swiss Federal Institute of Technology, Zurich, Switzerland
'48 Yeager, Lee E., Wildlife Research Unit, Fort Collins, Colo.
'49 Yoder, A. W., Phoenix, Ariz.
'47 Yoder, C. Troy, Dept. of Conservation, Plainwell, Mich.
'28 Yorke, R. H., % State Hatchery, Route 3, Arlington, Washington
'41 Zilliox, Robert G., 30 Main St., Saranac Lake, N. Y.
'49 Zimmer, Paul D., U. S. Fish Hatchery, Clackamas, Ore.

STATE MEMBERSHIP

'36 Alabama Department of Conservation, Montgomery, Ala.
'38 Arkansas State Game & Fish Commission, State Capitol Bldg., Little Rock, Ark.
'22 Connecticut Board of Fisheries & Game, State Capitol, Hartford, Conn.
'36 Idaho Department of Fish & Game, Boise, Idaho
'26 Illinois Department of Conservation, Springfield, Ill.
'21 Indiana Div. of Fish and Game, Indianapolis, Ind.
'21 Iowa State Conservation Commission, Des Moines, Iowa
'21 Louisiana Wildlife & Fisheries Department, Fish & Game Division, 126 Civil Courts Bldg., New Orleans, La.
'26 Maine Department of Inland Fisheries & Game, State House, Augusta, Me.
'22 Maryland Department of Tidewater Fisheries, State Office Bldg., Annapolis, Md.
'21 Massachusetts Div. of Fisheries and Game, 20 Somerset St., Boston, Mass.
'38 Michigan Department of Conservation, Lansing, Mich.
'21 Minnesota Dept. of Conservation, State Office Bldg., St. Paul 1, Minn.
'32 Missouri State Conservation Commission, Jefferson City, Mo.
'36 Nebraska Game, Forestation, & Parks Commission, Lincoln, Nebr.
'34 New Hampshire Fish & Game Department, Concord, N. H.

'25 New Jersey State Fish & Game Commission, Trenton, N. J.
'41 New Mexico State Game Commission, Santa Fe, N. M.
'36 North Carolina Wildlife Resources Comm., Raleigh, N. C.
'26 Oklahoma State Game & Fish Commission, Oklahoma City, Okla.
'41 Ontario, Province of, Department of Lands & Forests, Parliament Bldg., Toronto, Ont.
'39 Oregon Game Commission, 616 Oregon Bldg., Portland, Ore.
'49 Pennsylvania Fish Commission, 230 S. Office Bldg., State Capitol, Harrisburg, Pa.
'47 Pennsylvania Game Commission, Harrisburg, Pa.
'41 Quebec, Province of, Department of Fish and Game, Quebec, P. Q.
'39 Tennessee Department of Conservation, Nashville 3, Tenn.
'39 Texas Game, Fish, & Oyster Commission, Austin, Tex.
'37 Vermont Fish & Game Service, State Office Bldg., Montpelier, Vt.
'41 Virginia Commission of Game and Inland Fisheries, Richmond, Va.
'39 Washington State Game Commission, Seattle 4, Wash.
'36 West Virginia Conservation Commission, Charleston, W. Va.
'23 Wisconsin Conservation Department, 830 State Office Bldg., Madison 2, Wis.
'27 Wyoming Game and Fish Commission, Cheyenne, Wyo.

CLUBS AND DEALERS

'36 Arundel Corp., Pier 2, Pratt St., Baltimore, Md.
'38 Chittenden County Fish & Game Club, Inc., 26 University Terrace, Burlington, Vt.
'49 Dorion Hermanos y Cia—Peguasa, 5a Ave. y 10a Calle, Guatemala, Central America
'39 Gladding & Co., Inc., B. F., South Otselic, New York
'22 Massachusetts Fish and Game Assoc., 20 Spruce St., Boston, Mass.
'27 William Mills and Sons, 21 Park Place, New York, N. Y.
'21 Paradise Brook Trout Co., Cresco, Pa.
'21 Pennsylvania State Fish and Game Prot. Assoc., Land Title Bldg., Philadelphia, Pa.
'27 Plymouth Rock Trout Co., Box 75, Plymouth, Mass.
'11 Pohoqualine Fish Assoc., 1420 Walnut St., Philadelphia, Pa.
'21 Porter's Lake Hunting and Fishing Club, 925 West Huntington St., Philadelphia, Pa.
'42 Sixteen Island Lake Fishing Club, Inc., 1100 Craig St., E. Montreal, P. Q.
'36 Smith Bros., Port Washington, Wis.
'47 Sportsmen Club of Northern Westchester, Katonah, New York
'39 Von Hoffman Press Club, 101 South 9th St., St. Louis, Mo.
'28 Weber Lifelike Fly Co., Stevens Point, Wis.
'39 Wildlife Institute, 822 Investment Bldg., Washington, D. C.

LIBRARY MEMBERSHIP

'23 American Museum of Natural History, 77th St. and Central Park West, New York, N. Y.
'20 Atlantic Biological Station, St. Andrews, N. B.
'44 Bingham Oceanographic Laboratory, Yale University, New Haven, Conn.
'28 California, Division of Fish and Game, Bureau of Research and Education, Ferry Building, San Francisco, Calif.
'21 California State Fisheries Laboratory, Terminal Island Station, San Pedro, Calif.
'38 California, University of, Berkeley 4, Calif.
'37 Connecticut State College, Storrs, Conn.
'37 Enoch Pratt Free Library, Cathedral, Franklin, and Mulberry Streets, Baltimore, Md.

'43 Fisheries and Game Library, 605 Flanders Street, Melbourne C3, Australia
'38 Fisheries Section, Fisheries Reservation, Cronulla, New South Wales, Australia
'38 Fishery Research Institute, P. O. Box 728, St. John's, Newfoundland
'38 Freshwater Biological Assoc., Wray Castle, Ambleside, Westmoreland, England.
'20 Harvard University, Cambridge, Mass.
'22 Illinois, University of, Urbana, Ill.
'20 Indiana University, Bloomington, Ind.
'48 Institute of Biology, University of Montreal, Montreal, P. Q.
'41 International Pacific Salmon Fisheries Comm., Westminster Trust Building, New Westminster, B. C.
'21 John Crerar Library, 86 E. Randolph Street, Chicago, Ill.
'49 Louisiana State University, Periodical Division, Baton Rouge 3, La.
'49 Loyola University, New Orleans, La.
'37 Maine, University of, Orono, Maine
'49 Manitoba Provincial Library, Legislative Buildings, Winnipeg, Man.
'49 Marine Biological Laboratory, Woods Hole, Mass.
'36 Massachusetts State Library, State House, Boston, Mass.
'37 McGill University, Redpath Library, 3459 McTavish St., Montreal, P. Q.
'49 Miami, University of, Marine Laboratory, 511 Anastasia Avenue, Coral Gables, Fla.
'39 Montana State University, Missoula, Mont.
'38 Mount Holyoke College, South Hadley, Mass.
'21 Nebraska, University of, Lincoln, Neb.
'39 New Hampshire, University of, Hamilton Smith Library, Durham, N. H.
'18 New York Public Library, 476 Fifth Avenue, New York, N. Y.
'22 New York State College of Agriculture, Ithaca, N. Y.
'49 Notre Dame, University of, Notre Dame, Ind.
'27 Oregon State Agricultural College, Corvallis, Ore.
'39 Pacific Biological Station, Nanaimo, B. C.
'22 Portland, Library Assoc. of, 10th and Yamill Sts., Portland, Ore.
'38 Quebec, Library of the Legislature, Quebec, P. Q.
'37 Queen's University, Kingston, Ont.
'49 Rochester, University of, Rochester 3, N. Y.
'39 Saskatchewan, University of, Saskatoon, Sask.
'21 Scripps Institution of Oceanography, La Jolla, Calif.
'49 St. Louis Public Library, Olive, 13th and 14th Sts., St. Louis 3, Mo.
'21 Toronto, University of, Toronto, Ont.
'38 U. S. Fisheries Laboratory, 2725 Montlake Blvd., Seattle, Wash.
'44 Victoria Fish and Game Dept. Library, Office of Chief Inspector, Melbourne C3, Australia
'42 Washington, State College of, College Station, Pullman, Wash.
'19 Washington, University of, Acquisitions Division, Seattle 5, Wash.
'49 Wyoming, University of, Laramie, Wyo.

INDEX TO VOLUME 78

A

Age composition, smelt, 179
  sucker, longnose, 24-25
  and growth, chub, lake, 21
    sucker, longnose, 20
    trout, brook, 20
      lake, 19
      rainbow, 18
    whitefish, mountain, 17
Aldrich, A. D., 4, 209
Algonquin Park, Ontario, 133-145
Alosa sapidissima, 40
Ambloplites rupestris, 82, 171
Ameiuridae
  Ameiurus melas, 146
    natalis, 39, 67, 89
    nebulosus, 66, 89
      marmoratus, 39
    platycephalus, 39
  Ictalurus catus, 39
    lacustris, 66
      punctatus, 39
Amiidae
  Amia calva, 39, 165
Anabantidae
  Anabas, 94
Anderson, A. W., 3, 217-219
Anderson, Bertil G., 96-113
Angling, improvement, 13-31
Aquatic biology and physics, division, report of, 214-216
Ariidae
  Arius, 94
Area, 94
Asterionella, 15, 135-137, 139

B

Bacteria, ulcer disease, description of, 58-59
Bacterium salmonicida, 56-57, 59-62, 117, 119-122, 124-126, 182-184, 186
Bag limits, results of removal, 64-69
Bailey, Reeve, M., 2, 4-5, 243-244, 253
Baldwin, N. S., 176-180
Ball, Robert C., 145-155
Barbour, Thomas, (*In memoriam*), 8
Barker, Elliott S., 252
Bass, black, 39
  largemouth, 65-69, 83, 146, 163, 165-169, 171-172
    growth fluctuation, 87-90
—panfish lakes, 163-175
  rock, 67-68, 165-166, 171-172
    growth computation, 157-161
      rate, increase of, 82
  smallmouth, 146
Beckman, William C., 82-90, 252
Bluegill, 65-69, 83-84, 89-90, 146, 165, 173
  growth, fluctuation, 86-88
    icrements, 85
  toxicity threshold, 104-105
Bode, I. T., 209
Bond, Lyndon, 189-191
Bonito, 94
Bosmina, 16
Bottom fauna, effects of dams on, 70-81
Bowfin, 39, 165
Briggs, John C., 70-81
Buffalo, 173
  bigmouth, 165-166
Bullhead, 165-166, 168-169, 171-173
  black, 67-68, 146
  brown, 65-68, 89
  flat, 39
  management, 40
  speckled, 39
  yellow, 39, 67-68, 89
Burdick, George E., 192-202
Burrows, Charles R., 163-175
Business sessions, 203-254
  agenda, 205
  appointment of committees, 209
  concluding business, 254
  remarks of president, 206-208
  reports of committee, 220-253
    of officers, 210-219.

C

California stream, effects of dam on bottom fauna, 70-81
Campbell, R. S., 252
Carangidae
  Caranx, 94
Carassius auratus, 100
Carchariidae
  Carcharias, 94
Carp, 94, 163, 165-166, 173
Carpiodes cyprinus, 165
Carry, C. R., 252
Castalia odorata, 64
Catch, analysis, smelt, 178-179
  data, Minnesota lakes, 163-175
  total in United States, 217
    composition of, 217
Catfish, 94
  channel, 39, 66-67
  management, 40
  White, 39
Catostomidae
  Carpiodes cyprinus, 165
  Catostomus catostomus, 17
    lacustris, 20
    commersonnii, 66, 83, 171
  Erimyzon sucetta, 39
    kennerlii, 83
  Megastomatobus cyprinella, 165
  Moxostoma aureolum, 165
Centrarchidae
  Ambloplites rupestris, 82, 171
  Chaenobrytus coronarius, 39
  Lepomis auritus, 39
    cyanellus, 66
    gibbosus, 67, 87, 146, 165
    macrochirus, 39, 66, 83, 104, 146, 165
    megalotis, 67
    microlophus, 39
    punctatus, 39
  Micropterus, 39
    dolomieu, 146
    salmoides, 66, 83, 146, 163, 165

Pomoxis, 163
annularis, 66
nigro-maculatus, 39, 165
Ceratium, 15-16
Ceriodaphnia laticaudata, 100
reticulata, 103, 109
Chaenobryttus coronarius, 39
Chanidae
Chanos salmoneus, 94
Chaoborus, 152
Chara, 14
Chironomus, 64
plumosis, 152
Chlorides, toxicity thresholds of *Daphnia*, 96-113
Chub, creek, 131
lake, 17
age and growth, 21
Chubsucker, 83, 89
lake, 39
Chute, Walter H., 4, 253
Cichlidae
Etroplus, 94
Cirrhina mrigala, 94
Clark, M. F., 209
Clemens, W. A., 4-5, 253
Clupeidae
Alosa sapidissima, 40
Clupea ilisha, 94
Dorosoma cepedianum, 39, 66
Pomolobus aestivalis, 40
Sardinella longiceps, 94
Cobb, Kenneth E., 3
Columbia river, fishery development, 42-55
Committees, list of, 4-5, 209
reports of, 220-253
sessional, list of, 209
auditing, 245-246
nominations, 252-253
resolutions, 246-251
time and place, 245
special, list of, 5
establishment of quarterly journal, 243-244
formation of Western division, 241-242
revision of constitution and by-laws, 240-241
standing, list of, 4
editorial board, 239
international relations, 220-232
state and national relations, 232-239
Competitors, effects of removal of, 28-29
Coregonidae
Coregonus clupeaformis, 100, 176
Prosopium williamsoni, 17
Cottidae, 180
Couesius, 20
plumbeus, 17
Crappie, 163, 165-166, 168-169, 171-172
black, 39-40, 68, 83
white, 66-68
Creel census, Minnesota, 168-169
results with liberalized fishing, 65-69
Christivomer namaycush, 17, 176
Crowe, Walter R., 2
Crustacea
Bosmina, 16
Ceriodaphnia laticaudata, 100
reticulata, 103, 109
Cyclops, 16, 21, 140-141
vernalis, 101, 103
Daphnia, 16, 18, 97, 100, 103, 105-106, 108, 110-112
longispina, 16, 100, 102-104, 109
magna, 96-113
pulex, 16, 100, 103-104, 109
thomsoni, 103
Diaphanosoma, 16
Diaptomus, 16, 141
oregonensis, 101
Gammarus, 16, 18-21
Goniosoma natator, 94
Hyalella, 16, 21
Leptodora, 18
kindtii, 101
Megacyclops leuckarti, 103
Moina macrocopa, 103
Mysis relicta, 180
Neptunus gladiator, 94
Peneopsis monoceros, 94
Pleuroxus aduncus, 101
Polycelis nigra, 103
Pontoporeia, 180
Thenus orientalis, 94
Xantho scabberus, 94
Curtis, Brian, 2, 4
Cyanide, ferro-ferric, toxicity to fish, 192-202
Cybium, 94
Cyclops, 16, 21, 140-141
vernalis, 101, 103
Cynoglossidae
Cynoglossus, 94
Cyprinidae
Carassius auratus, 100
Couesius, 20
plumbeus, 17
Cyprinus carpio, 163
Hybognathus regius, 200
Hyborhynchus notatus, 66
Labeo, 94
Notemigonus crysoleucas, 68, 83, 102
Notropis atherinoides, 200
cornutus, 131
Rhinichthys a. atratulus, 199-200
Schizothorax, 94
Semotilus atromaculatus, 131, 199-200
Cyprinodontidae
Fundulus heteroclitus, 108
Cypselurus, 94

D

Dam construction, fishery protection in, 216
effects on bottom fauna, 70-81
on fishery, 43-46
Daphnia, 16, 18, 97, 100, 103, 105-106, 108, 110-112
longispina, 16, 100, 102-104, 109
magna, 96-113
pulex, 16, 100, 103-104, 109
thomsoni, 103
Dasyatidae
Trygon, 94
Davis, George W., 4-5
Day, Albert M., 4, 252
DDT, 215-216
Deason, H. J., 4-5, 209, 240-241, 246-251
Dendy, J. S., 5
Dequine, John F., 38-41
Dianthera americana, 64
Diaphanosoma, 16
Diaptomus, 16, 141
oregonensis, 101

Dinobryon, 15-16, 135-137, 139
Diptera
Chaoborus, 152
Chironomus, 64
plumosis, 152
Disease, ulcer in trout, 56-63
Dorosoma cepedianum, 39, 66
Dymond, John R., 4, 253

E

Echinodermata
Holothuria atra, 94
edulis, 94
mormorata, 94
sabra, 94
Eggleton, Frank E., 5
Elsey, C. A., 13-31
Erimyzon sucetta, 39
kennerlii, 83
Eschmeyer, R. W., 3, 5
Esocidae
Esox americanus, 39
lusius, 131, 146, 163
niger, 39
vermiculatus, 68
Etroplus, 94
Exocoetidae
Cypselurus, 94
Exostoma, 94

F

FAO, report on, 224
work of, 218
Feast, C. N., 252
Fertilization, Michigan lakes, 145-155
Ontario lakes, 133-145
Fish, commercially important, India, 94
culture, division of, report, 211-214
pounds per acre, Minnesota, 165-167
Fisheries, India, status of, 91-95
Fishery, development, Columbia river, 42-55
legal history of, 232-234
missions, reports on, 220-221
protection, relation to dams, 216
Fishing, commercial, division, report of, 217-219
Florida, history, 39-40
liberalized, results of, 64-69
recreational value, 39
selectivity, various gear, 168-173
vessels, number in India, 92
Fishways, Columbia river, construction of, 52-53
Flakas, Kenneth G., 117-127
Florida, fisheries management, 38-41
Flyingfish, 94
Food, of, Smelt, 179-180
sucker, longnose, 21, 23
trout, brook, 20, 23
lake, 19, 23
rainbow, 18, 23
whitefish, mountain, 18, 23
Foster, Frederick J., 5
Fragillaria, 135-136
Friddle, S. B., 56-63, 181-188
Fukano, Kiyoshi G., 2
Furunculosis, 56-57
sulfonamide therapy, 117-127
treatment in brook trout, 181-188
Fundulus heteroclitus, 108

G

Gammarus, 16, 18-21
Gar, Florida, 39
longnose, 39
shortnose, 165, 173
spotted, 39
Gasterosteidae
Gasterosteus aculeatus, 103
Gill nets, Minnesota indices, 169-171
perch problems, 173-174
selectivity, 172-173
Glaridacris catostomi, 21
Glyptosternon, 94
Goldfish, toxicity threshold, 100, 104-110
Goniosoma natator, 94
Gordon, Seth, 3, 5, 252
Gottschalk, John, 4-5
Gowanloch, James N., 4-5, 209, 220-232
Crammes, J. Frank, (*In memoriam*), 8
Greeley, John R., 209
Greenbank, John, 32-37
Greene, A. F., 5
Growth, chub, lake, 21
control chart, Atlantic salmon, 189-191
fertilized lakes, in, 152-153
increment, bluegill, 85
nomograph for computation of, 156-162
sucker, longnose, 20
trout, brook, 20
lake, 19
rainbow, 18
whitefish, mountain, 17
Growth rates, changes due to winterkill, 82-90
fluctuation of, 84-90
bass, largemouth, 88
bluegill, 86-88
perch, yellow, 88
pumpkinseed, 88
Gutermuth, C. R., 4, 209, 252
Gutsell, J. S., 181-188

H

Harkness, W. J. K., 5, 209, 252
Hart, John L., 5
Hatchery, Columbia river, 53-54
production costs, 212-213
Hazzard, A. S., 5, 252
Hemiramphidae
Hemiramphus, 94
Hemophilus, 56, 59
Herbicides, use of, 215-216
Herring, glut, 40
Herring, William C., 5
Heydecker, Wayne D., 4, 232-239
Hildebrand, Samuel F., 4, 253
Hile, Ralph, 2, 4-5, 156-162, 209, 239
Holothuria atra, 94
edulis, 94
mormorata, 94
sabra, 94
Hoop nets, Minnesota indices, 171-172
Hunter, Russell P., 3, 210-211
Huntsman, A. G., 5, 252
Hyalella, 16, 21
Hybognathus regius, 200
Hyborhynchus notatus, 66

I

Ictalurus catus, 39
lacustris, 66
punctatus, 39

India, fisheries, 91-95
Insecticides, use of, 215-216
International relations, committee, report of, 220-232
  Fisheries Commission (Halibut), 228-229
  Pacific Salmon Fisheries Commission, 229-232
ITC, report on, 224-226
ITO, work of, 218-219
Iyengar, H. D. R., 91-95

J

James, Milton C., 3, 252
Japanese fisheries, 227-228

K

Keratella, 141
King, Willis, 5, 252
Kingsbury, Oliver, R, 3, 211-214
Kuehn, Jerome H., 163-175

L

Labeo, 94
Lake Alma, Ohio, 64-69
  Erie, water and added chlorides, toxicity, 96-113
  fertilization, effects of, 147-152
  Ontario, streams, reintroduction of salmon, 128-132
Langford, R. R., 133-145
Langlois, T. H., 5
Latidae
  Lates calcarifer, 94
Laythe, Leo L., 42-55
Length, removal of legal, results, 64-69
Leonard, Justin W., 2, 4-5
Lepisosteidae
  Lepisosteus osseus, 39
    platostomus, 165
    platyrhincus, 39
    productus, 39
Lepomis auritus, 39
  cyanellus, 66
  gibbosus, 67, 87, 146, 165
  macrochirus, 39, 66, 83, 104, 146, 165
  megalotis, 67
  microlophus, 39
  punctatus, 39
Leptodora, 18
  kindtii, 101
Linder, M. J., 252
Lipschuetz, Morris, 192-202
Loligo, 94
Lutjanidae
  Lutjanus, 94

M

MacKay, H. H., 3, 206-208
Mackerel, horse, 94
Madsen, Marion J., 5
Management, Florida fisheries, 38-41
  lower Columbia river, 48-53
Manuscripts, instructions for preparation of, 257-260
Margaritifera vulgaris, 94
McCrimmon, Hugh R., 128-132
McKenzie, R. A., 114-116
Meehean, O. Lloyd, 5, 209, 245, 252
Megacyclops leuckarti, 103
Megastomatobus cyprinella, 165
Melosira, 135-136
Members, list of, 261-268
Michigan lakes, fertilization of, 145-155
Microcystis, 15
Micropterus, 39
  dolomieu, 146
  salmoides, 66, 83, 146, 163, 165
Milkfish, 94
Minnesota lakes, fish populations in, 163-175
Minnow, bluntnose, 65-66
Moina macrocopa, 103
Mollusca
  Area, 94
  Loligo, 94
  Margaritifera vulgaris, 94
  Ostrea, 94
  Pisidium, 16
  Rostellaria, 94
  Triton, 94
  Turbonella, 94
  Voluta, 94
Mortality, cyanide toxicity, cause of, 192-202
  furunculosis, 182-187
Moxostoma aureolum, 165
Moyle, John B., 163-175
Mugilidae
  Mugil, 94
Mullet, 94
Myers, George S., 4, 253
Mysis relicta, 180

N

Needham, Paul R., 3, 5, 214-216
Neptunus gladiator, 94
Nomograph, for growth computation, 152-162
Notemigonus crysoleucas, 68, 83, 102
Notholca, 15, 141
Notopteridae
  Notopterus, 94
Notropis atherinoides, 200
  cornutus, 131
Nymphaea advena, 64
  odorata, 146

O

O'Donnell, D. John, 32-37
Officers, list of, 3
  reports of, 210-219
Omand, Douglas, 5
Oncorhynchus keta, 43
  kisutch, 43
  nerka, 43
  tschawytscha, 43
Ophicephalidae
  Ophiocephalus, 94
Osmeridae
  Osmerus mordax, 114, 176-180
Osphronemidae
  Osphronemus goramy, 94
Ostrea, 94

P

Pelton, John Z., 64-69
Penopsis monoceros, 94
Perch, blue, 94
  yellow, 67-68, 83-84, 146-147, 163, 165-169, 171-173
    gill net problems, 173-174
    growth fluctuation, 87-88

Percidae
Perca flavescens, 67, 87, 146, 163
Stizostedion v. vitreum, 100, 163
Philippine fisheries, report on, 222-223
Photodecomposition, cause for high toxicity, 192-202
Pickerel, chain, 39
grass, 68
redfin, 39
Pike, 131, 146, 163, 165-169, 171-174
Pikeperch, yellow, 163, 165-166, 168-169, 171-174
toxicity threshold, 100, 102
Pisidium, 16
Plankton, increase with fertilization, 134-142
Plantings, Atlantic salmon, 128-132
Plants
Anabaena, 15
Asterionella, 15, 135-137, 139
Bacterium salmonicida, 56-57, 59-62, 117, 119-122, 124-126, 182-184, 186
Castalia odorata, 64
Chara, 14
Dianthera americana, 64
Fragillaria, 135-136
Hemophilus, 56, 59
Melosira, 135-136
Microcystis, 15
Nymphaea advena, 64
odorata, 146
Potamogeton, 14
amplifolius, 146
natans, 146
Pseudomonas hydrophila, 56
Scirpus, 64
Tabellaria, 135-137, 139
Typha, 64
Platyhelminthes
Glaridacris catostomi, 21
Pleuroxus aduncus, 101
Pollution, abatement, 51
text animal, 97
Polyarthra, 141
Polycelis nigra, 103
Polynemidae
Polynemus, 94
Pomfret, 94
Pomolobus aestivalis, 40
Pomoxis, 163
annularis, 66
nigro-maculatus, 39, 165
Pontoporeia, 180
Population density, changes in growth, 82-90
estimation of, 26-28
Minnesota lakes, fish in, 163-175
reduction of, 13-31
Potamogeton, 14
amplifolius, 146
natans, 146
Predaceous fish, relation to population, 163-167
Predation, by birds, 131
on salmon fry, 131
Presidents, past, list of, 6-7
remarks of, 206-208
Press, hydraulic scale impression, 32-37
Pristidae
Pristis, 94
Productivity, above and below dams, compared, 75-77
changes due to fertilization, 134-143
pools and riffles, compared, 80-81
Prosopium williamsoni, 17
Protozoa
Ceratium, 15-16
Dinobryon, 15-16, 135-137, 139
Synura, 135
Pseudecheneis, 94
Pseudomonas hydrophila, 56
Public information on research and stocking, need for, 214-215
Pugsley, Winfield B., (*In memoriam*), 8
Pumpkinseed, 67-68, 83-84, 146, 165
growth fluctuation, 87-88
Pyramid lake, Alberta, 13-31

Q

Quillback, 165

R

Rawson, D. S., 13-31
Reavley, William L., 5
Redhorse, northern, 165
Refuges, fish, Columbia river, 54
Reid, Kenneth A., 5
Rhinichthys a. atratulus, 199-200
Rodd, James A., 4-5, 252
award of honorary membership, 250-251
Rostellaria, 94
Rotifera
Keratella, 141
Notholca, 15, 141
Polyarthra, 141
Rough fish, removal of, 167-168
Rounsefell, George A., 2, 4, 189-191

S

Salmon, catch and value of, 43
Atlantic, growth control chart, 189-191
predation on fry, 131
reintroduction into lake Ontario streams, 128-132
chum, 43
India, 94
king, 43, 47
red, 43-44, 47, 230-231
silver, 43
sockeye, 230-231
Salmonidae
Cristivomer namaycush, 17, 176
Oncorhynchus keta, 43
kisutch, 43
nerka, 43
tschawytscha, 43
Salmo gairdnerii, 17, 43, 59, 71, 147, 242
salar, 128-132, 189-191
trutta, 59, 117-127, 147
Salvelinus fontinalis, 17, 56, 71, 114, 131, 147, 181-188
Salts, metal, toxicity thresholds of *Daphnia*, 96-113
Sardinella longiceps, 94
Scale impressions, hydraulic press for, 32-37
measurements, growth computation from, 156-162
Schizothorax, 94
Schneberger, Edward W., 5, 209
Schultz, Leonard P., 4, 253
Scirpus, 64
Scombridae
Cybium, 94
Scomber, 94

Season, removal of closed, results, 64-69
Secretary-treasurer, report of, 210-211
Semotilus atromaculatus, 131, 199-200
Serranidae
Serranus, 94
Shad, 40
gizzard, 39, 66
Sheepshead, 165-166
Shiner, common, 131
golden, 68, 83
toxicity threshold, 102
Simpson, James C., 3
Sisoridae
Exostoma, 94
Glyptosternon, 94
Pseudecheneis, 94
Smelt, age composition, 179
American, 176-180
catch analysis, 178-179
food, 179-180
spawning run, 177-178
tagged, 114
mortality from, 116
recaptures, 115
Smith, Lloyd L., 2, 4, 252
Snapper, 94
Snieszko, S. F., 5, 56-63, 181-188
Sole, 94
South Bay, Manitoulin Island, Lake Huron, 176-180
Speaker, E. B., 252
Sprecher, George E., 252
State and national relations, committee, report of, 232-239
Stickleback, threespine, toxicity threshold, 103-110
Stizostedion v. vitreum, 100, 163
Stocking, salmon, size at, 190
Stromateidae
Stromateus, 94
Sucker, longnose
age composition, 24-25
age and growth, 20
food, 22
reduction of population, 13-31
spawning, 21
northern, reduction of population, 13-31
white, 66, 68, 83, 165-166, 171-173
Sulfadiazine, 181-182, 213
Sulfaguanidine, 117, 120-121, 125-127
Sulfamerazine, 117, 120-123, 125-127, 181-188
Sulfamethazine, 181-182
Sulfanilamide, 181-182
Sulfathiazole, 181-182
Sulfonamide, furunculosis treatment, 117-127, 181-188
Sunfish, 165-169, 171-172
bluegill, 39
green, 66-68
longear, 39, 67-68
redear, 39
spotted, 39
yellowbelly, 39
Surber, Eugene W., 209, 245-246
Synura, 135

T

Tabellaria, 135-137, 139
Taft, Alan C., 4-5, 209
Tag, opercular, celluloid, 114-116
Thenus orientalis, 94
Thompson, Fred A., 4-5, 209, 241-242, 252
Toole, Marion, 5, 209, 252
Toxicity thresholds, chlorides, *Daphnia*, 96-113
goldfish, 100
pikeperch, 100
whitefish, 100
cyanide, 192-202
Treaties, reports on, 223-224
Triton, 94
Trout, 108
brook, 17, 27, 71, 131, 147
age and growth, 20
food, 20
furunculosis treatment, 181-188
mortality, tagging, 114, 116
ulcer disease in, 56-63
brown, 147
furunculosis treatment, 117-127
ulcer disease in, 56-63
hatchery, 211-214
lake, 17, 27-30
age and growth, 19
food, 19
smelt as factor in production, 176
spawning, 19
rainbow, 17, 27-28, 71-72, 147, 242
age and growth, 18
food, 18
introduced into India, 93
ulcer disease in, 56-63
steelhead, 43
catch and value of run, 47
ulcer disease in, 56-63
Trygon, 94
Turbonella, 94
Typha, 64

U

Ulcer disease, etiology of, in trout, 56-63
mortality from, 60-63

V

Van Oosten, John, 4, 252
Voluta, 94

W

Walleye lakes, 163-175
Warmouth, 39
Weight per acre, fish, Minnesota lakes, 165-167
Westerman, Fred A., 209
Whaling, report on, 226
Whitefish, lake, production, smelt as factor, 176
toxicity threshold, 100, 102
mountain, 17, 27-28
age and growth, 17
food, 18
Wickliff, E. W., 5
Winterkill, bass-bluegill ratio, 83-84
growth rate, effect on, 82-90
Wright, Stillman, 209, 252-253

X

Xantho scabberus, 94

2, 4-D, 215-216